BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD

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REPORT ON SYMPOSIUM ON QINGHAI-XIZANG (TIBET) PLATEAU

Beijing and southern Tibet. May-June, 1980

by

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SUMMARY

The multidisciplinary Symposium on Qinghai-Xizang (Tibet) Plateau is described. The symposium in Beijing was attended by 79 non-Chinese scientists from 18 countries and 205 Chinese scientists. 259 papers were presented, covering 10 major scientific disciplines. About 80 non-Chinese guests and 100 Chinese participated in the excursion, which journeyed 950 km across southern Tibet. The symposium revealed a wealth of new scientific data accumulated by scientists of the People's Republic of China since 1965.

The Tibet Plateau is the largest single elevated block in the world, with an area of 2.4 million km^2 and average elevation of 4500-5000 m. The Tibet Plateau has formed by the successive accretion of continental and/or island arc fragments between late Palaeozoic and Cainozoic.

The principal accretionary block is the Indian Subcontinent, which collided with Eurasia in early Tertiary and created the Himalaya Mountain Range. Southern Tibet provides spectacular exposure of the results of this event - opening of the Tethys ocean in Triassic; convergance and subduction in Late Cretaceous-Eocene; collision in late Eocene-early Oligocene; underthrusting and metamorphism of the Himalayas in mid-late Tertiary; upift of the Tibet Plateau and Himalayas in Quaternary. The great uplift of the Plateau is the result of isostatic adjustment to crustal thickening, which took place due to crustal shortening during intercontinental convergence.

The insight provided by the magnificently exposed mountain belt demonstrates that plate tectonics, and particularly Tibetan-style collision phenomena, may well provide an adequate mechanism of formation of Proterozoic, apparently ensialic, mobile belts.

INTRODUCTION

The Qinghai-Xizang (Tibet) Plateau is situated in the western part of the People's Republic of China. It lies between the Kunlun Mountains to the north, the Himalayas to the south, the China border to the west, and the so-called Hengduan (Three Rivers) Mountains (roughly the southern Sanjiang and Bayankala Fold Systems) to the east (Figs. 1, 2). It covers an area of about 2.4 million km^2, one-quarter of the total area of China, and has an average altitude of 4500-5000 m, making it the largest single elevated mass in the world. The Tibet Autonomous Region only occupies the southwestern half (1.2 million km^2) of the Plateau.

Foreign access to Tibet has been restricted for centuries by both terrain and politics, and scientific data is scarce in the western world. Only in the last couple of years has the Chinese government allowed restricted entry by selected foreigners, mostly just to Lhasa and its environs. Chinese scientists have been carrying out extensive research in Tibet over the last 15 years, but only very limited results have been available.

As part of the Chinese government's new liberalisation policies, Academia Sinica conducted a multidisplinary Symposium on Qinghai-Xizang (Tibet) Plateau in Beijing from May 25 - June 1, 1980, followed by a field excursion across southern Tibet from June 2-14. Attendance was by invitation, which I was privilaged to receive. I presented a paper entitled "Precambrian tectonics, viewed from the Himalayas and the Qinghai-Xizang Plateau".

The symposium was significant in terms of both international relations and contribution to scientific knowledge. To the best of my knowledge the symposium represented:

1) The first major international scientific symposium within the People's Republic of China;

2) The first time that the new scientific data from Tibet was released internationally;

3) A rare or even unique attempt to address so many scientific disciplines (10) to one problem (Tibet Plateau).

The importance of the meeting to China was evidenced by the honour of an official reception for us in the Great Hall of the People, hosted by Senior Vice-Premier Deng Xiou-ping (also Vice-Chairman of Communist Party) and Vice-Premier Fang Yi. Similarly, we were given a banquet in Lhasa by several Vice-Premiers of the People's Autonomous Government.

The plateau and adjacent Himalayas lie in a key position in the Alpine-Himalaya Chain (Fig. 1). The plateau encompasses the major part of the suture zone of the India-Eurasia collision, and thus provides the classic model of a continent-continent collision. The mechanism of the plateau uplift is fundamental to geotectonic theory. The height, size, and rapid rise of the plateau and surrounding ranges make it of great importance to many other sciences - biological evolution, meteorology, physiology, and so on.

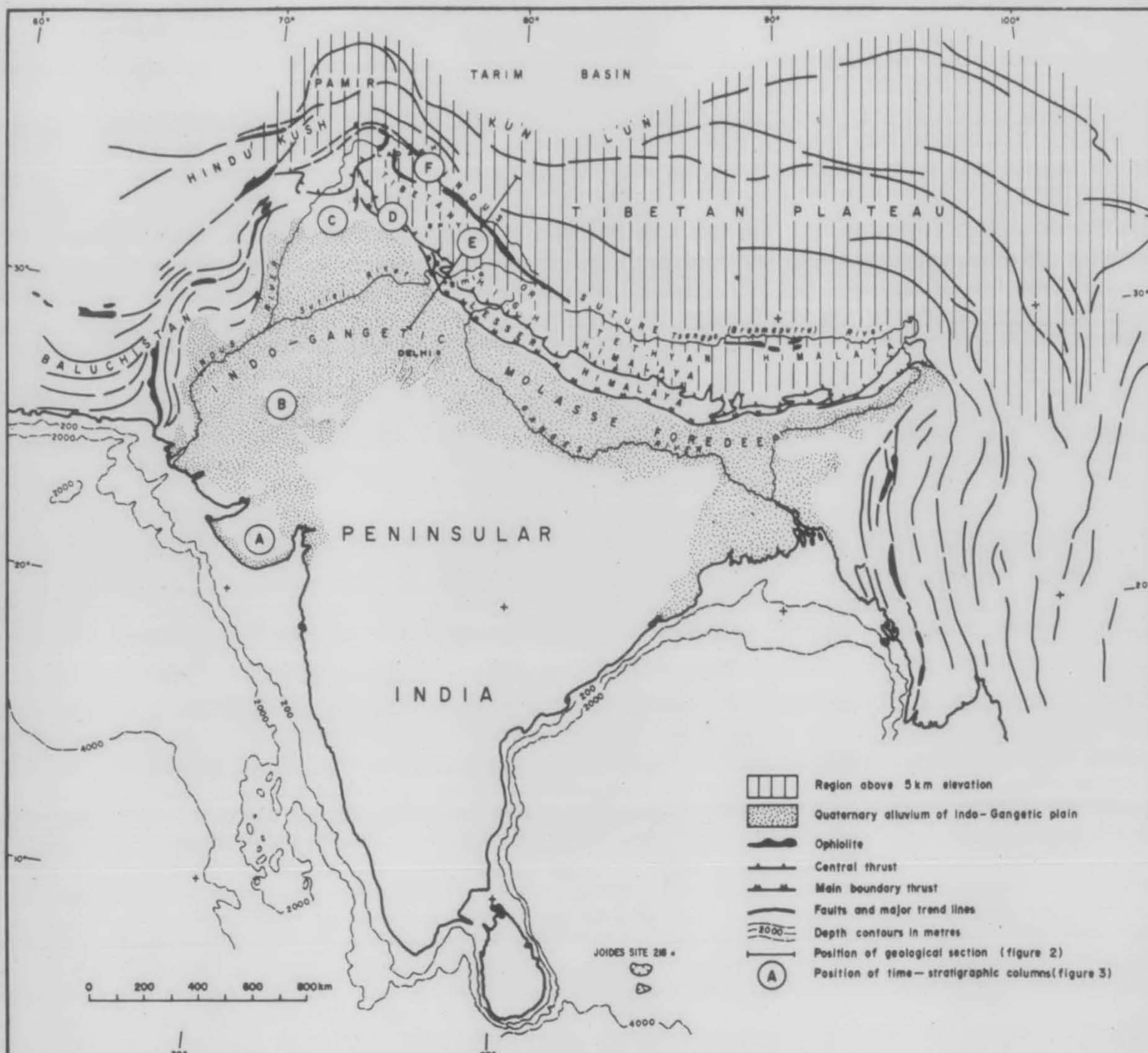

Figure 1. Regional tectonic map of the Himalaya and Tibet Plateau and adjoining regions (Powell & Conaghan, 1973).

This report summarises the results of the meeting and my analysis of the observations and hypotheses presented therein. For simplicity, authors of the numerous papers referred to (Academia Sinica, 1980a) will not always be quoted, except in particularly significant cases.

PHYSIOGRAPHY AND CLIMATE

The Tibet Plateau is a dissected plateau resulting from some 4000 m of uplift and erosion since the beginning of Pleistocene (1 m.y.); some parts are still rising at 1 cm/year. East-west trending, geologically-controlled ranges, 5500-7000 m in elevation, alternate with broad river valleys and tectonically-controlled basins 3500-5000 m high. The plateau is bordered to the north and south by higher ranges dropping off rapidly to peripheral lowlands - the 6000-8000 m Himalayas and <200 m Ganges Plain to the south and west; the 6000-7000 m Kunlun Mountains and 2000 m Tsaidam and Tarim Basins to the north. In the east, the Hengduan Mountains drop off rapidly to the <1000 m Yangtze Platform around Chengtu (Fig. 1). The Tibet Plateau is the source of the great rivers of Asia - the Indus, Brahmaputra (Yarlung Zangbo), Salween, Mekong, Yangtze, and Yellow Rivers.

What is considered to be the main plateau surface is a Pliocene planation surface of undulating hills and ridges, broad tectonically-controlled valleys and basins, and valley shoulders, now forming a broad basin tilted to the southeast: 5200 m elevation in the piedmonts of the Kunlun and Himalaya Mountains; about 4500 m between, in northern Tibet and Qinghai (Chang Tang Plateau); about 4000 m and less in the Hengduan Mountains to the southeast. An earlier Oligocene-Miocene planation surface is preserved in the higher 6000-7000 m ranges.

The Pliocene surface is most extensive in the Chang Tang Plateau of northern Tibet and southern Qinghai, to the north of the Kangdese and Nyainqentanghla Ranges; many authors confine the real Tibet Plateau to this area. With an interior drainage system into tectonic basins and lakes and low rainfall, dissection is minimal here and the Pliocene surface is essentially intact, between higher ranges such as Kangdese, Tanggula, Kekexili, and Kunlun.

In southern and southeastern Tibet headward erosion by the major streams is extensive and the plateau surface is extensively dissected. The Pliocene surface is preserved as peneplain remnants covered by Pleistocene glacial deposits, by areas of Pliocene lake deposits, and by remnants of Pliocene karst. River valleys are now eroded to elevations of 4500 m around Tingri, 4000 m at Gyangse, 3650 m at Lhasa, and 2000 m or lower in the Hengduan Mountains. With ranges rising to 6000-7000 m local relief is commonly of the order of 2000 m.

In southern Tibet the snowline is around 5500 m, decreasing northwards to 5200 m in the Kunlun Mountains. Glacial landforms and glaciers predominate above this altitude, and periglacial phenomena down to about 5000 m. Fluvial action is dominant below this. Moraines from Pleistocene ice ages are common down to about 4500 m in places.

The physiography of the Plateau and the border ranges is reflected in the climate. The Plateau acts as a giant heat source, both solar and possibly geothermal, and serves to moderate temperatures, while the Himalaya and Hengduan Mountains serve as almost total barriers to monsoon rainfall. Southern Tibet, between Lhasa and Tingri, has a plateau-temperate

TABLE 1.

PARTICIPANTS - SYMPOSIUM ON QINGHAI-XIZANG (TIBET) PLATEAU

CHINESE (By discipline)		FOREIGN (By country)	
Organising Committee	- 36	Australia	- 3
Geology	- 25	Bangladesh	- 1
Geophysics	- 36	Canada	- 1
Geochemistry	- 16	France	- 11
Palaeontology	- 18	West Germany	- 7
Zoology	- 17	India	- 2
Botany	- 25	Italy	- 4
Physiology	- 7	Japan	- 5
Geomorphology	- 22	Nepal	- 3
Geography	- 27	Netherlands	- 1
Meteorology	- 12	New Zealand	- 1
		Pakistan	- 1
		Sweden	- 1
		Switzerland	- 3
		Turkey	- 1
		U. K.	- 8
		U. S. A.	- 25
		Yugoslavia	- 1
Total	205	Total	79

semi-arid climate. Annual mean temperatures, at 3500–4500 m elevation, are 1°C–7.5°C, ranging between 10°C–15°C summer-mean and around −10°C– −15°C winter mean. Annual rainfall is only 200–450 mm, falling mostly in summer as snow or rain. Rainfall increases gradually eastwards to >500 m in the Hengduan Mountains, while it increases dramatically across the Himalayas to 600 mm and more on the southern slopes. Northwestwards from Lhasa, rainfall falls off rapidly to 100–250 mm, and temperatures steadily decrease with latitude, to produce a frigid-arid climate. Much of the northwest Tibet Plateau is uninhabited desert.

Most of Tibet's 1.5 million people live in the southern valleys, where almost all agriculture - highland barley, winter wheat, peas, potatoes, rape, and other crops - takes place. The northern plateau steppes are sparsely inhabited by hardy nomadic herdsmen with yaks, sheep, goats, and cattle. In southern Tibet nomadic herdsmen live up to 5000 m, just below the snowline.

THE SYMPOSIUM

MEETING - BEIJING

Participants

The symposium was attended by 205 Chinese scientists, and 79 non-Chinese scientists from 18 countries (Table 1), plus 17 wives. Australia had 3 participants: C.T. Klootwyk (A.N.U.), and J.M. Dickins and K.A. Plumb (BMR). My wife, Lyn, although officially an "accompanying guest", participated in activities of relevance to the Baas-Becking Laboratory.

TABLE 2.

PAPERS PRESENTED - SYMPOSIUM ON QINGHAI-XIZANG (TIBET) PLATEAU

BY SUBJECT AND SPEAKER

		CHINESE	FOREIGN	TOTAL
1.	Geology (mostly tectonics)	22	20	42
2.	Geophysics	23	9	32
3.	Geochemistry	16	1	17
4.	Stratigraphy & Palaeontology	16	9	25
5.	Zoology	16	6	22
6.	Botany	24	5	29
7.	Physiology	12	5	17
8.	Geomorphology (incl. glaciology)	24	7	31
9.	Geography	20	9	29
10.	Meteorology	12	3	15
	Total	185	74	259

TABLE 3.

PAPERS PRESENTED IN EARTH SCIENCES (BY SUBJECT)

SYMPOSIUM ON QINGHAI-XIZANG (TIBET) PLATEAU

GEOLOGY		GEOPHYSICS		GEOCHEMISTRY		STRATIGRAPHY		GEOMORPHOLOGY	
Tectonics	- 26	Seismic	- 13	Granites	- 7	Palaeontology	- 19	Glaciology	- 13
Petrology	- 8	Geothermal	- 8	Hydrothermal	- 8	Sedimentology/ stratigraphy	- 6	Hydrology	- 6
Other	- 8	Gravity/ aeromag.	- 3	Isotopic ages	- 2			Landforms	- 10
		Palaeomag.	- 2					Permafrost	- 4
		Other	- 6					Soils	- 1
Totals	42		32		17		25		34

Location

The symposium was held at the "West Beijing Hotel" (Fu-hsing Lu), about 9 km west of Tien-an Men Square. This is an Army conference centre and proved ideal. We lived on site. The conference rooms were excellent. Because we were the sole guests, the kitchens absolutely excelled themselves. Being a military establishment, access was restricted, but no trouble was experienced by any participants.

Program and organization

Papers were divided into 10 sections (Table 2). Up to 8 concurrent sessions were conducted at any one time. Of a total of 259 papers, 185 were presented by Chinese and 74 by foreign scientists. The majority of papers (150) were presented in the earth sciences or related fields (Table 3).

The operating language was English and simultaneous translations were provided. Authors supplied texts in advance for translation. Most Chinese authors read their papers in English, and these were simultaneously translated into Chinese for the Chinese audience. Some read them in Chinese, and commonly these were preferable because the translator's English was easier to understand.

Papers were spread over 7 days, including 3 half-day cultural visits. Days were divided into 4 sessions of about 1½ hours each. Individual papers were generally assigned 20 minutes plus discussion.

Projection facilities were good, compared to my 1978 visit to China. New Kodak Carousel projectors were used.

Publications

Participants were provided with a 320-page volume of Abstracts, and an excellent 100-page Excursion Guidebook to Southern Xizang (Tibet), accompanied by a specially produced coloured geological map (1:1 500 000). Various new publications were available for sale, mostly in fields outside my interest, and drafts of a new series of geological maps of the Tibet Plateau were exhibited - Geology, Tectonics, Metamorphism, Magnetic Rocks, from memory. Most are in press at present and look to be very useful. Landsat images of the excursion area and a new topographical map of the Plateau were on sale.

All papers presented to the Symposium are to be published in a special volume. Papers are restricted to 6 printed pages, except for a selected few Chinese papers which will contain important new data. This volume should be a very significant contribution to the scientific literature.

Impressions

I think that the Symposium exceeded the expectations of all visitors; it certainly exceeded mine. The lecturing facilities were excellent. Timetables were adhered to. Chinese papers were presented according to a standardised format and were probably rehearsed, and this did much to overcome language problems.

Cultural visits were much more informal than in 1978, and there were absolutely no limitations on movements. There has been a dramatic change in freedom of movement, informality, and attitude to visitors in China Between 1978 and 1980.

Many of the foreign scientists have worked in the Himalayas for many years. Most of their papers were repeats of old ideas, but most were new to me. Their presence certainly enhanced discussion. The most distinguished geologist present, in my view, was Prof. A. Gansser, who has worked throughout the Himalayas since 1936, when he surreptitiously entered Tibet, and is author of the 1964 book - "Geology of the Himalayas". Others included 83 year-old Prof. A. Desio, with many decades of work in the Karakorum; Patrik LeFort and Michel Colchen, authorities on the geology of Nepal; Kevin Burke of 'Dewey and Burke' fame; and Profs. I.G. Gass and R.M. Shackleton from U.K. Prominent seismologists included Leon Knopoff and Peter Molner from U.S.A. Other sciences included people of similar stature, such as S. Dillon Ripley, Director of Smithsonian Institution, Washington.

The feature was the wealth of new data on Tibet presented by the Chinese. There was a very obvious trend towards integrating the studies of all the sciences with the history of uplift of the plateau. It is perhaps a pity that the concurrent sessions limited one's opportunity to hear more of these other sciences.

EXCURSION - TIBET

Participants

We were not provided with actual numbers, but I estimate that about 80 foreigners, including 15 wives, and about 100 Chinese came to Tibet.

Route

The group flew into Lhasa from Chengtu. After a few days in Lhasa, we travelled by road through Gyangse, Xigaze, Tingri, and Zham (Fig. 2); about 950 km in all. Most visitors crossed into Nepal and exited via Kathmandu; some returned to Lhasa and Beijing. The Geological Society of Nepal gave a geological tour from Zham to Kathmandu, so effectively we traversed right across the greater part of the Himalayas.

The following geological features were traversed (Fig. 2):

Kangdese-Nyainqentanghla Fold Belt: Yangbajain geothermal field, in Quaternary glacial deposits. Granite-granodiorite batholiths and calc-alkaline volcanics of the Kangdese granitoid belt. Late Palaeozoic-Mesozoic stratigraphy and structural style of the Fold Belt.

Yarlung Zangbo Suture Zone: Petrology and imbricate structure of tectonically-emplaced Cretaceous ophiolites - harzburgite, gabbro, serpentinite, pillow basalt, radiolarian chert - and associated flysch. Molasse deposits, derived from ophiolite. Fault contacts with adjacent tectonic zones.

North Tethys-Himalaya Subbelt: Mesozoic melange, olistostromes, flysch, and exotic blocks adjacent to Yarlung Zangbo Suture Zone. Variations in structure and stratigraphy away from Suture Zone.

South Tethys-Himalaya Subbelt: Early Palaeozoic to Eocene continental-shelf stratigraphy. Thrust-fault tectonics. Pleistocene lake deposits.

High Himalaya Subbelt: Miocene high-grade metamorphism of Precambrian basement. Thrust-fault tectonics. Quaternary glacial topography.

Low Himalaya Subbelt (Nepal): Miocene low to high-grade metamorphism of Early Palaeozoic-Late Proterozoic sediments. Reverse metamorphism. Polycyclic folding.

Organization

Accommodation: Lhasa has the only guesthouse in Tibet. In Xigaze and Tingri we were accommodated in Army Officers' quarters. A new tourist hotel is under construction in Zham; we were accommodated in the partly completed building. While travelling, we commonly had tea-breaks at very hospitable Army camps, scattered at regular intervals along the main roads. New bedding was transported in specially for our group to Xigaze and Tingri.

Meals were all Chinese style, with food specially imported for the occasion; seafood figured prominently. The kitchen and dining-room staffs travelled with us throughout the excursion.

Transport: New Toyota minibuses were mostly used. Some people travelled in Chinese-built, Russian-designed, 4-wheel drive vehicles. People of similar interests travelled in the same bus. I travelled with a "tectonics group" - Gansser, Desio, Le Fort, Molnar, etc.

Problems

There was an obvious logistics problem, with the number of participants and lack of facilities in Tibet. Clearly, a tremendous amount of preparation and work behind the scenes during the excursion resulted in a remarkably smooth trip.

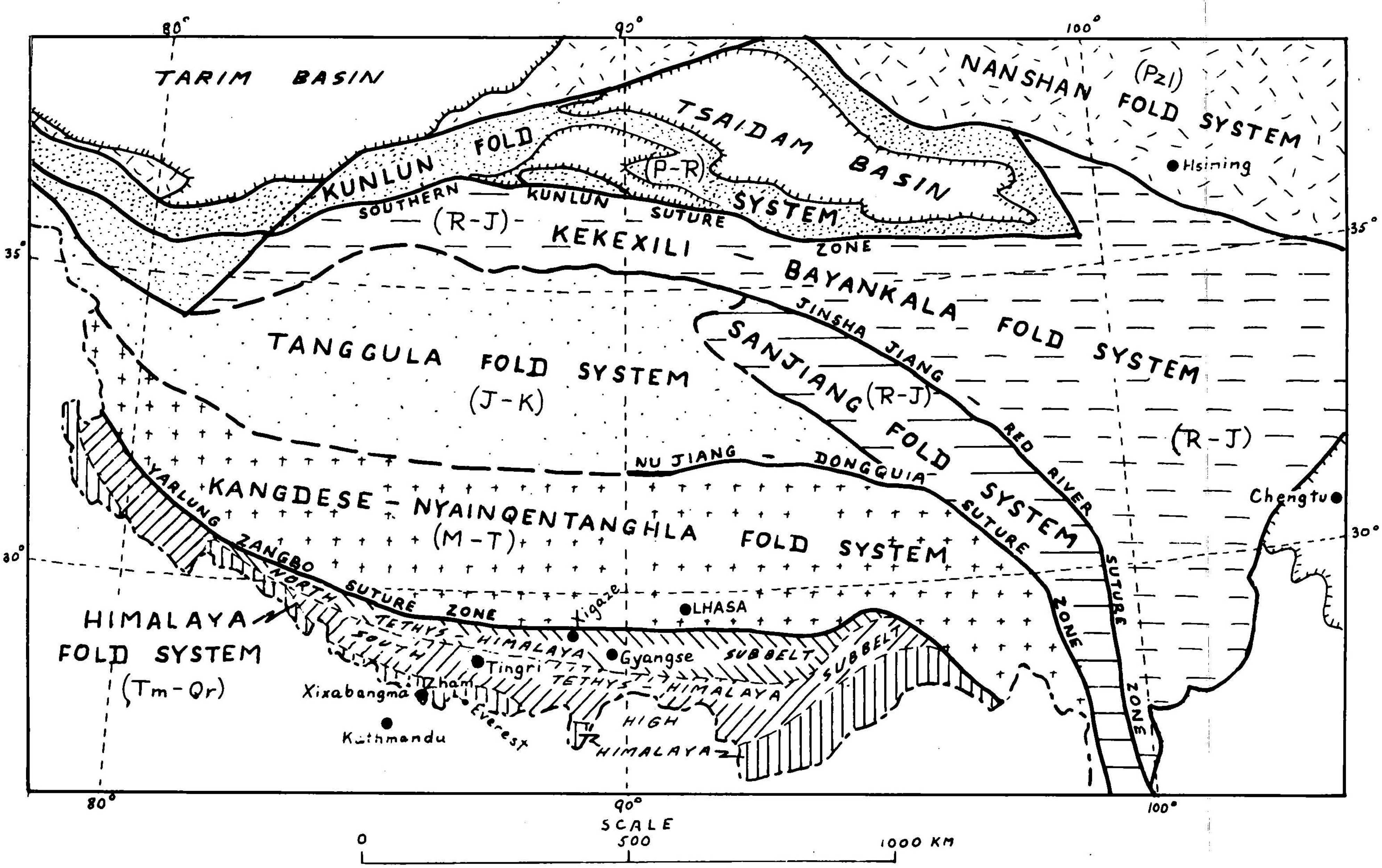

Figure 2. Tectonic provinces and locality sketch map; Qinghai - Xizang (Tibet) Plateau.

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The diversity of interests made scheduling difficult. The excursion had been originally designed as a geological trip, but all the biologists wanted to come too. They were accommodated by allowing them to select their stops almost at will; this obviously favoured the more persuasive individuals. The planned geological trip clearly favoured tectonics and petrology so, after the first day, the palaeontological bus diverged from program and 'did their own thing'; ultimately they possibly achieved the most fruitful trip of all. The geological program proved to be too full, and organisers did not enforce time limits at stops rigidly enough (there were, of course, several uncooperative visitors); consequently, we generally missed many stops and much of the geology had to be observed on the move. For regional structure and tectonics, this was not too much of a problem.

Landslides in the Himalayas (monsoon season) closed the road for several days, and only a tremendous effort by the Chinese and Tibetans cleared the road in time for us to get through to Zham; we had thought that we would all have to return to Lhasa. This lost us more than two days due to modified schedule, and further restricted our stops at geological sites. We still saw most of the later areas though, albeit in half the programmed time.

Finally, there was the altitude. The lowest point was Lhasa (3500 m), and we crossed three passes at greater than 5000 m. We flew straight into Lhasa from 300 m. Officially, 15% of Europeans suffered acute mountain sickness; 3 were evacuated with respiratory problems; there was one mild heart attack. I suspect that the 15% were only those who admitted their symptoms, and the Chinese seemed to have a similar incidance. Considering that we were all people engaged in regular fieldwork, and probably one-third or more of the visitors worked regularly above 4000 m, the 15% represented an unexpectedly high proportion, probably about 30% of the visitors new to high altitude. The physiologists had forecast about 10%.

Impressions

The two immediate impressions are the huge amount of effort by the Chinese in organizing and overcoming the problems of the excursion, and the wonderful friendliness and hospitality of the Tibetan people we met. One cannot fail to obtain permanent memories of the unique temples and other cultural features of Tibet, and to become involved in wishing to learn more of their cultural heritage and history.

Climatically the area is much drier than one would have anticipated, and the terrain more rugged than a plateau usually implies in Australia. I found the terrain often similar to parts of southern California. The contrast in climate and vegetation across the Himalaya can only be described as dramatic. The lack of trees was a constant problem to the biologists - is it natural (i.e. climatic) or have they been stripped by man? Similarly, the most recent gullying of piedmont fans - latest uplift or man-induced erosion? There was a strong plea by the biological group for increased need for conservation and management of the environment and resources.

Geological exposures are excellent, although the combined effects of altitude and terrain make detailed studies a daunting prospect. The region certainly represents a classic region for the study of the effects of continental collision and mountain building processes.

SCIENTIFIC RESEARCH IN TIBET

PREVIOUS INVESTIGATIONS

Apart from some observations around the periphery of the Plateau, the only geological data available from Tibet for Gansser's (1964) "Geology of the Himalayas" seems to have come from three sources: Hedin carried out expeditions across northwest Tibet in 1894-97, 1899-1902, 1906-08, and rock samples were described by various workers, particularly Hennig (1916). Hayden travelled with the Younghusband Expedition of 1903, and made observations between Sikkim and Lhasa (e.g. Hayden, 1907). Gansser made three surreptitious reconnaissances into southern Tibet during work in the Kumaon Himalaya during 1936 (Heim & Gansser, 1936). It is expected that the status of work in other sciences was similar.

Throughout this period, and up to the present, many workers in all sciences have been working in the Himalayas. This has involved studies of many rock units continuous into Tibet, and thus has provided some insight into Tibetan geology. Principal areas of interest have been the Karakorum, Ladakh, Kumaon Himalaya, and Sikkim-Bhutan Himalaya.

PRESENT CHINESE RESEARCH

Following Liberation of Tibet, Academia Sinica has carried out many multidisciplinary expeditions to Tibet. In all, some 400 scientists and technicians have been involved in fieldwork, and 1200 in laboratory investigations in Tibet. It is this new data which has been the reason for the Symposium. To summarize it, one can do no better than refer to Liu Tung-sheng's opening address (Appendix 1).

EARTH SCIENCE RESEARCH

As in the rest of China, systematic geological mapping in Tibet seems to be the responsibility of the Ministry of Geology, while Academia Sinica is involved in more fundamental research of particular topics. It was not possible to judge the map coverage or reliability of basic mapping, although the excursion map (compiled by Academia Sinica) did have some rather obvious errors in places. Remote sensing images have been utilised by the Ministry to compile a 1:1.5 million map of the Plateau.

Academia Sinica's work appears to be almost all in southern Tibet; most data on the main or northern Tibet (Chang Thang) Plateau seems to be by the Ministry of Geology mapping teams. Academia Sinica particularly concentrates on the following:

1) Palaeontology;
2) Geochemistry of granitoids;
3) Petrology of ophiolites;
4) Megastructure and uplift of the Plateau;
5) Seismology;
6) Geothermal studies.

The State Seismological Bureau, Ministry of Geology is also carrying out a great deal of seismological analysis.

Impressions

The work in the topics just mentioned is of high standard, and seems to utilise all modern concepts and techniques, where appropriate technology is available. It represents a wealth of valuable new data.

Although a great deal has been achieved, there is still much to be done. Field observations seem to be fairly broad-scale at present and most detailed work is in fields which emphasize laboratory study - palaeontology, petrology, geochemistry. There is particular need for:

1) Detailed structural analysis;
2) Integrated structure/metamorphic petrology. The metamorphic petrology considers only gross assemblages and seems to ignore polymetamorphism or relative ages of phases;
3) Isotopic age determinations. Most data is only K-Ar. Sparse Rb-Sr and zircon work indicates strange anomalies;
4) More detailed study of selected stratigraphic sections. Even on the excursion, many new palaeontological discoveries were made. Sedimentology can be improved.

The conclusions, interpretations, and models proposed by the Chinese almost everywhere agree with those previously proposed by European geologists, from work in surrounding regions or from sparse data from Tibet. This may reflect a lack of originality, but I rather feel that it indicates brilliant perception by the earlier European reconnaissance workers. This is not to degrade the Chinese work, because the Tibet Plateau is the key to the region, and thus will prove or disprove the earlier concepts. Similarly, there is very good integration and agreement between the various Chinese studies, although several dissenting views support my conclusion of adequate originality and independent thought.

I was particularly impressed by much of the theoretical modelling of crustal conditions and evolution based on seismic, geothermal, and gravity considerations, although the mathematics was beyond my expertise.

It represented quite advanced work to me. Also notable was a 430 km long explosion seismic profile across Tibet and into the High Himalayas. This has greatly improved on some of the analysis of natural earthquakes, it has significantly modified the deep structure beneath the Himalaya (c.f. Qureshy, 1971), and prompted pleas for more international cooperation to extend such studies right across the Himalaya into the Ganges Plain.

OTHER SCIENCES

Some of the more striking results have come from the non-geological fields. There is an impressive coordination of many of these other studies with the history of uplift of the Plateau.

Palaeobotany has probably provided the most precise dating of the uplift of the Plateau, particularly by use of spores. At the end of Pliocene the Plateau was still no more than 1000 m high. This is supported by vertebrate palaeontology, soils, Pliocene karst, palaeoclimatology, and so on. As the Himalayas rose, during Pleistocene, they gradually formed a barrier to animal and bird migration and a unique isolated flora and fauna evolved on the Plateau. Many instances are available - fish, reptiles, mammals, etc. - whose evolution and adaptation to the plateau uplift have been studied.

Because of its size and height, the Tibet Plateau is a major influence on weather systems and climate throughout Asia. Some workers suggest that it influences climates as far away as North Africa and the Rocky Mountains of U.S.A. Visiting meteorologists expressed the view that the Chinese work on the Plateau is of very high standard, and is apparently leading the world in some aspects of forecasting.

Similar opinions were expressed about their physiological research into adaptation to altitude. One British physician expressed the view that the Chinese doctors were doing research on some aspects that had not even been thought of yet in Europe. Tibet provides a unique natural laboratory for such studies, because of the numbers of lowland Chinese who are deployed to Tibet for long periods, generally 5 years. Apparently some people never adapt, and have to be repatriated. One discovery, previously not anticipated, is that after a long assignment to Tibet people suffer reverse symptoms and have to readapt, after their return to low altitudes.

In summary, these examples serve to reinforce the impression of the quality of Academia Sinica's research on the Tibet Plateau.

GEOLOGICAL AND TECTONIC OUTLINE

REGIONAL SETTING

The Tibet Plateau is a region of massive block uplift to the north of the Himalayas (Fig. 1), the highest mountain chain in the world and part of the Cretaceous-Recent chain which extends from the Alps to Indonesia. It is part of the zone of interaction and collision between fragmented elements of Gondwanaland and Eurasia. It includes the major part of the 2400 km-long Yarlung Zangbo Suture Zone (Indus Suture Zone of Gansser, 1964), which is the generally accepted northern margin of the Indian Subcontinent.

Following Academia Sinica, the Tibet Plateau is considered here to include everything north of the High Himalaya Range, and so includes the Tibetan or Tethys Himalaya (Fig. 1).

TECTONIC PROVINCES

The Tibet Plateau comprises a series of Phanerozoic fold belts, progressively younging from north to south (Fig. 2). Data on the northern belts are sparse. Ancient sutures, most containing some ophiolites and adjacent calc-alkaline plutonic-volcanic belts, and some with melange, separate the belts. The Qinghai-Xizang (Tibet) Plateau seems to have formed by the successive accretion of continental and/or island arc fragments between late Palaeozoic and Cainozoic (Chang Cheng-fa et al., 1977; Chang Cheng-fa & Pan Yu-sheng, 1980). Figure 2 uses the terminology of Chang Cheng-fa and Pan Yu-sheng (1980), with some modification according to the Tectonic Map of China (Academy of Geological Sciences, 1977).

The Nanshan and Kunlun Fold Systems were formed during the Caledonian and Variscan Cycles respectively, by closing of the Nanshan and Southern Kunlun Suture Zones (Academy of Geological Sciences, 1977). The Nanshan, in particular, displays eugeosynclincal characteristics with widespread ophiolites and glaucophane recorded.

The Kèkexili-Bayankala Fold System displayed miogeosynclinal characters through the late Palaeozoic-early Mesozoic, while the Sanjiang Fold System developed eugeosynclinal ophiolites and mélange along the very important Jinsha Jiang-Red River Suture Zone. Folding took place with closing of the suture during the important Indosinian Cycle (Triassic-Jurassic) (Academy of Geological Sciences, 1977). The Tectonic Map of China describes the Tanggula Fold System as Yenshanides (late Mesozoic), but later data (Chang Cheng-fa et al., 1977; Zheng Yan-zhong, 1980) describe Devonian-Triassic geosynclinal rocks folded during the Indosinian Cycle, and overlain by Jurassic-Cretaceous shelf limestones. It was further folded and intruded by Cretaceous granite during the Yenshanian closing of the Nu-Jiang-Dongquia Suture Zone.

The Kangdese-Nyainqentanghla Fold System has a Precambrian continental basement, overlain by Palaeozoic-Mesozoic platformal deposits. It separated from Gondwanaland in the Triassic, and was attached to the Tanggula Fold System and folded during the late Mesozoic Yenshanian Cycle. A calc-alkaline granite-granodiorite belt and associated volcanics and metamorphism developed during late Cretaceous-Eocene subduction of Tethys oceanic basement down the Yarlung Zangbo Suture. With final closing of the Tethys Ocean, the Indian Subcontinent collided with Eurasia at the Suture, and further deformed the Kangdese- Nyainqentanghla Fold System during the Cainozoic Himalayan Cycle.

The Himalayan Fold System is the mountain range formed along the northern edge of the Indian Subcontinent during the Cainozoic Himalayan Cycle - the collision and intracontinental convergence between India and Eurasia. It contains a Precambrian continental basement, overlain by a almost continuous early Palaeozoic-Eocene continental-margin platformal sequence. Mesozoic geosynclinal rocks, developed on Tethys oceanic crust, occur along the northern edge. Metamorphism and granite emplacement accompanied the Himalayan Cycle.

The Yarlung Zangbo Suture Zone (Indus Suture-Gansser, 1964; Indus-Tsangpo or Himalayan Suture Zone-Gansser, 1980) is the most important structure in the Himalaya-Tibet region (Gansser, 1980). It may be traced continuously for 1000 km across northern Pakistan and Ladakh, 2000 km across Tibet, and then ultimately joins with an ophiolite belt in Burma (Fig. 1). Thick ophiolites and related flysch are exposed through much of its length. It is the principal suture between the Indian Subcontinent and Eurasia, formed during the final Eocene-Oligocene closing of the Tethys Ocean.

Discussion

Various palaeontological data indicate that during the early Palaeozoic all the provinces of the Tibet Plateau had related faunas, of Asiatic and Australian affinity. Apparently they were then all part of Pangea.

The late Palaeozoic of the Kangdese-Nyainqentanghla and Himalaya blocks have glacial rocks and Gondwana faunas, while the faunas of the northern provinces are of Eurasian or Tethyan type. The Tanggula and Sanjiang provinces had oceanic character from mid-Palaeozoic to mid-Mesozoic, and Tethyan oceanic faunas.

The Jinsha Jiang-Red River Suture Zone, and to lesser extent the Nu Jiang-Dongquia Suture Zone, may be major features, almost comparable to the better known Yarlung Zangbo Suture Zone. All of the suture zones (Fig. 2) have at least some ultrabasic or ophiolitic rocks, some have high-pressure minerals, and most have adjacent belts of granitoids which may reflect subduction. Many have granitoids of similar age on both sides, so their evolutions are difficult to interpret at this stage.

Perhaps the Jinsha Jiang-Red River Suture Zone should be considered as the southern edge of stable Eurasia, and the Yarlung Zangbo Suture the northern edge of the Indian Subcontinent. The Tanggula, Sanjiang, and Kangdese-Nyainqentanghla blocks would then represent the Tethyan oceanic, microcontinent, and suboceanic zone of interaction between them. Powell (1979) describes a similar set of twin sutures - the Herat-Hindu Kush and Indus Sutures with microcontinents and island arcs between - in northern Pakistan, and Kravchenko (1979), in the same area, describes very well the history of continental accretion. However, the collision

AGE	TECTONIC EVENT	LOW HIMALAYA & SUBHIMALAYA	SOUTH TETHYS-HIGH HIMALAYA	NORTH TETHYS HIMALAYA	YARLUNG ZANGBO SUTURE ZONE	KANGDESE NYAINQENTANGLA
QUATERNARY	ISOSTATIC UPLIFT	Siwalik Molasse, Subhimalaya: Underthrust - MBF, MFT. Folds, thrusts Siwalik. Uplift.		ISOSTATIC UPLIFT OF HIMALAYA & TIBET PLATEAU Conglomerate, moraine, fluvioglacial deposits. (U N C O N F O R M I T Y)		
PLIOCENE	INTRACONTINENTAL	Underthrust - MBF. Overthrusts in Low Himalaya.		PENEPLANATION OF TIBET PLATEAU SURFACE Lake deposits, karstic weathering.		
MIOCENE (Late Oligocene Early Pliocene)	CONVERGENCE	Intense folding, metamorphism, overthrusting - Low Himalaya	Underthrusting - MCT. Intense folding; metamorphism & S-type granite - 7-20 m.y.	Southward overthrusting and folding.	Thrusting: mostly north counterthrust? Molasse 500 m	North counterthrusts. S-type granite - 10-20 m.y. Molasse 4000 m
					(U N C O N F O R M I T Y)	
LATE EOCENE-OLIGOCENE	CONTINENTAL COLLISION	Regression Granite ca. 50 m.y.?	Regression ?	Underthrusting? Metamorphism, folding; S-type granite ca. 30 m.y.	Tectonic ophiolite emplacement; steep imbricate sheets. High-P metamorphism?	Folding, metamorphism. S-type granite - 30-50 m.y.
LATE CRETACEOUS TO EOCENE	CONTINENTAL CONVERGENCE & SUBDUCTION	Mid-Eocene transgression. Limestone, shale (H I A T U S)	Shelf limestone, shale, sandstone. (Cret.-Eoc.) 850 m	Oceanic trench. Olistostromes, flysch (Sth). Melange, high-P metamorphism (Nth).	Oceanic & island-arc submarine basalt. Radiolarian chert. | Flysch wedge 2500 m	I-type granite-granodiorite, metamorphism, 120-70 m.y. | Calc-alkaline volcanics. 2000 m. (UNCONFORMITY)
JURASSIC - EARLY CRETACEOUS	GONDWANA BREAKUP - WIDE TETHYS OCEAN	Shelf sandstone, limestone. 2000 m	Shelf limestone, sandstone, shale. 3300 m	Abyssal sandstone, shale, tuff. 2850 m		Sandstone, shale, coal, limestone. 2400 m
TRIASSIC	INDIA-KANGDESE SPLIT. OPENING TETHYS SEA	Shelf limestone, shale. 2000 m	Shelf sandstone, shale, limestone. 1600 m	Wildeflysch - Permian exotic blocks. Siltstone, sandstone. 1000 m		Shelf limestone, sandstone, shale, andesite. 2400 m
CARBONIFEROUS - PERMIAN	GONDWANA BASINS	Tillite, shale. 1500 m (UNCONFORMITY)	Shelf shale, limestone, sandstone, tillite. 3000 m.			Shelf limestone, sandstone, basalt. 1000 m+
ORDOVICIAN - DEVONIAN	CONTINENTAL BASINS (Pangea?)	Siltstone, sandstone, limestone, phyllite slate. 1000 m+	Shelf limestone, sandstone, shale. 1600 m			?
INFRACAMBRIAN	?	Phyllite, schist, dolomite, slate 4000 m	Phyllite, quartzite, marble, schist. 1 - 1000 m			?
		(U N C O N F O R M I T Y)				
PRECAMBRIAN	?	Gneiss, migmatite.	Gneiss, migmatite. 10 000 m			Granitic gneiss.

Table 4. Summary of tectonic and stratigraphic history - southern Tibet Plateau and Nepal Himalayas. (MBF - Main Boundary Fault; MFT - Main Frontal Thrust; MCT - Main Central Thrust).

of India, at the Yarlung Zangbo Suture, still remains the major event which affected all fold belts right across the Tibet Plateau.

TECTONIC EVOLUTION OF SOUTHERN TIBET AND HIMALAYA

The stratigraphy and tectonic evolution of this area, the area of main interest to the symposium, is summarized in Table 4.

Throughout late Precambrian and Palaeozoic the crustal blocks of the eventual Kangdese-Nyainqentanghla and Himalaya Fold Systems were probably part of the supercontinent, Pangea. During late Palaeozoic they were both part of Gondwanaland, separated from Eurasia by a Proto-Tethys ocean. An almost continuous succession of platformal sediments were deposited throughout these periods.

Kangdese-Nyainqentanghla split from Gondwanaland during the Triassic. Fragmental blocks of Permian limestone up to several kilometres across glided into the opening rift, producing wildeflysch. Abyssal sediments were deposited during Jurassic-Early Cretaceous in the widening Tethys, and shelf sedimentation continued on the continental blocks to north and south.

An unconformity between Lower and Upper Cretaceous probably reflects the late Mesozoic attachment of the Kangdese-Nyainqentanghla block to Eurasia. The Indian Subcontinent had, by this time, separated from Gondwanaland and so converged with Eurasia during Late Cretaceous-Eocene. Subduction of the Tethys oceanic crust produced a Cordilleran or Andean I-type calc-alkaline granitoid and volcanic complex, of mantle or lower crustal origin, in the Kangdese-Nyainqentanghla block, and olistostrome, flysch, and melange in the trench at the suture; the first stage of the Himalayan Orogenic Cycle.

A paired metamorphic belt of high and low-pressure metamorphics formed in the adjacent trench and calc-alkaline complexes respectively, either during this subduction stage and/or the later collision; the precise age is uncertain. Marine shelf sedimentation continued on the edge of the advancing Indian Subcontinent.

The Indian Subcontinent collided with Eurasia/Kangdese-Nyainqentanghla, at the Yarlung Zangbo Suture Zone, during Late Eocene-Early Oligocene, and the sea retreated. An ophiolite complex was obducted, followed by molasse derived from the uplifted ophiolite and granite belts. Syntectonic S-type gneissic two-mica granites, of crustal derivation, were emplaced into the North Tethys-Himalaya and Kangdese-Nyainqentanghla Fold Systems; these probably accompanied underthrusting and metamorphism, although none of the latter have been specifically ascribed to this period in the literature. Ophiolite and melange has been thrust up to 80 km south in the Kumaon Himalaya (Gansser, 1964) (Fig. 3), but it is unclear how much displacement is ascribed to the subduction, collision, or main Miocene thrusting; probably all have contributed.

Northward drift of the Indian plate accelerated again during Late Oligocene-Miocene, and was accommodated by intracontinental convergence between India and Eurasia; the culmination of the Himalayan Orogenic Cycle. The zone of underthrusting moved more than 200 km south, to the Main Central Thrust (MCT) between the High and Low Himalaya. Southward-directed thrusts and nappes developed throughout the Himalaya Fold System (Figs 3, 4); Gansser (1974) has estimated about 500 km of total crustal shortening for the Himalaya Fold System. In the north, counterthrusts thrust North Tethys-Himalaya rocks onto the ophiolites of the Yarlungzangbo Suture Zone, and the ophiolites were thrust in turn onto the Kangdese-Nyainqentanghla block. Syntectonic Barrovian-style metamorphism reached sillimanite grade

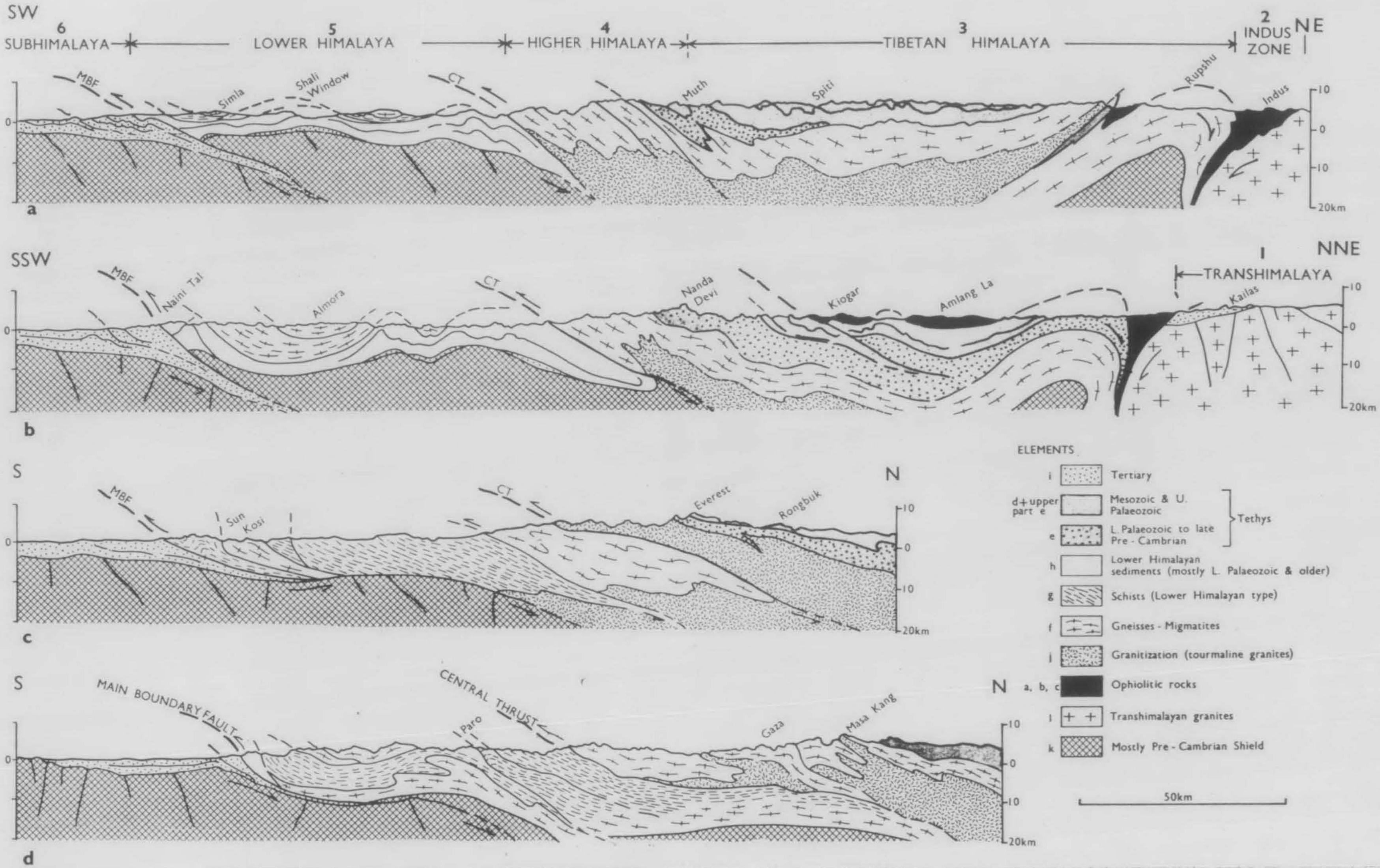

Figure 3. Structural profiles across the Himalayan orogen (Gansser, 1974).

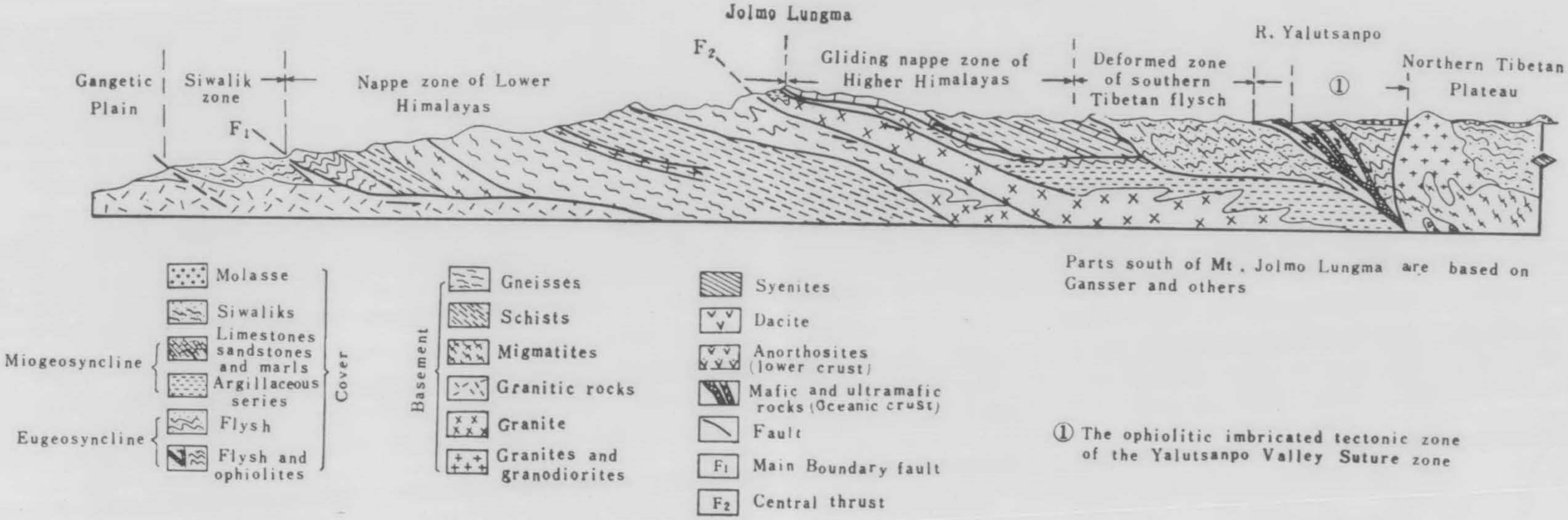

Figure 4. Schematic geological cross-section through the Jolmo Lungma (Everest) area of the Himalayas (Chang Cheng-fa et al., 1977).

at the base of the Precambrian slab above the MCT. Underthrusting of the Low Himalaya slab, and rebound overthrusting of the hot slab above the MCT, produced the unusual reverse metamorphism of the Low Himalaya, and partial melting of S-type late-tectonic tourmaline-muscovite granites in the High Himalaya, above the MCT (Figs 3, 4) (Le Fort, 1975). Siwalik molasse was deposited in the Subhimalaya.

Renewed convergence during Pliocene again shifted the zone of underthrusting southwards, to the Main Boundary Thrust (MBT) at the foot of the Low Himalaya (Figs 3, 4). Thrusting and folding continued in the Low Himalaya but, farther north, the Tibet Plateau was planated to a gently undulating surface, only about 1000 m high.

In Pleistocene rapid uplift commenced, which raised the Himalaya and Tibet Plateau some 4000 m to their present altitudes; some areas are still rising at 1 cm/yr. Underthrusting and molasse deposition continued in the Subhimalaya, where Low Himalaya rocks are now thrust (MBF) over deformed Siwalik molasse, and Siwaliks are thrust over Quaternary of the Ganges Plain (MFT) (Figs 3, 4). This is now the main active seismic zone of the Himalaya.

Discussion

The opening and closing of Tethys between the Kangdese-Nyainqentanghla block and the Indian Subcontinent, during Triassic-Eocene, is clearly evident from the stratigraphy of Tethys-Himalaya (Table 4) and from abundant palaeomagnetic evidence, although geology suggests that the opening may not be as great as that indicated by palaeomagnetism. The melange is particularly striking. Exotic blocks of Permian platformal limestone are enclosed in fossiliferous Triassic shales, and then Cretaceous ophiolites and fossiliferous sediments have been sheared into the rock; where we saw it the rocks formed a huge shear or thrust zone. The preferred explanation is that the Permian blocks were dropped in during initial Triassic rifting (olistostrome), and then the Cretaceous rocks were emplaced in the subduction zone (tectonic melange). Farther away from the subduction zone there are Cretaceous olistostromes - blocks of Cretaceous in Cretaceous shale. It is uncertain how much of the observed thrusting, particularly Gansser's (1964) blocks 80 km to the south, is subduction, Eocene collision, or the main Miocene thrusting.

The regional structure we saw is compatible with the model, but far more work is required to determine the ages of movements. Miocene is described as the main period of thrusting, particularly in High Himalaya, but logic demands that there have been considerable thrusting in the North Tethys Himalaya during Eocene collision, and probably during subduction. Perhaps the main thrusting migrated southwards with the movements of the underthrust zones - Yarlung Zangbo-MCT-MBF.

Structures within the Yarlung Zangbo Suture Zone are all subvertical, as expected by squeezing between two continental blocks. Young shallow thrusts at the margins, to both north and south, indicate the complex history of latest thrusting and back-thrusting. Southwards, across the Tethys Himalaya, steep upright cleavage folds grade into flat, south-vergent, recumbent folds and thrusts. All structures we saw in the High Himalaya have shallow north dips, parallel to the Main Central Thrust; greater complexity is described elsewhere. Complex polyphase folding in the Low Himalaya indicates the longer history of folding and nappe formation there.

The petrology and chemistry of the ophiolites is known in some detail. Because of tectonic disruption, their full stratigraphy is nowhere observed completely in situ, but the layers may be reconstructed as representing oceanic crust. The layers are, from base up: (1) serpentinized harzburgite with some dunite and lherzolite of "alpine-type"; (2) gabbro of abyssal tholeiite chemistry; (3) massive lava and spectacular pillow lava of abyssal tholeiite type; (4) interlayered radiolarian chert and lavas of island-arc or marginal sea type. Farther west, in Ladakh and Pakistan, the Dras Volcanics of the suture zone have much more island-arc character, while in Kohistan an inferred total island-arc, from basic granulites up to volcanics and sediments is described from between two branches of the suture zone (Tahirkheli et al., 1979).

This latter area was extrapolated eastwards at the symposium by Proust (France), to suggest that the main suture zone with Eurasia lay well to the north, perhaps the Nu Jiang-Donquia Suture Zone (Fig. 2). However, the Kangdese-Nyainqentanghla fold system is clearly a small continental block, not an island-arc (see stratigraphy, Table 4), and was attached to Eurasia before subduction at its southern margin. Clearly the Yarlung Zangbo Suture Zone is the major suture, which has absorbed a complex of different oceanic and suboceanic environments.

A variety of studies of the granitoid rocks - mineralogy and petrography, chemistry, fluid inclusions, feldspars, accessory minerals, and isotopes - all show consistent differences between the different belts. The 120-70 m.y. old Kangdese belt ranges from gabbro, through diorite and monzonite, to adamellite and granite, with abundant xenoliths. All data is consistent with derivation from the upper mantle or lowermost crust, above a subduction zone.

The younger 30 m.y. Lhagoi Kangri belt and 10-20 m.y. High Himalaya belt have combined features indicative of derivation from partial melting of continental crust; similar aged rocks were also emplaced into the Kangdese belt. The muscovite-biotite adamellites of the Lhagoi Kangri belt are highly foliated and clearly syntectonic (collision phase). The tourmaline-bearing granites of High Himalayan type are cross-cutting and clearly late tectonic, post-dating the peak of Miocene deformation. The High Himalayan granites are always found on the upper sides of thrusts (Figs 3, 4).

Several papers showed that the evolution of magmatism, particularly granitoids, is compatible with the models for evolution of the Plateau. Several geophysical papers presented mathematical models of the effects of crustal thickening, which indicated partial melting as a natural consequence. Le Fort presented his model (Le Fort, 1975), which showed why partial melting should occur above an underthrust zone.

Aspects of the metamorphism in the High Himalaya are very striking. In the Zham-Nyalam area some 20 km of Precambrian basement rocks have been remetamorphosed to medium-pressure high-amphibolite facies during Miocene, with assemblages such as staurolite-kyanite-sillimanite, sillimanite-muscovite etc. Kyanite only develops adjacent to or in thrust zones. A remarkably uniform foliation (clearly Miocene) parallels the dip of the Main Central Thrust for many kilometres. There are no relicts, in outcrop, of any of the inferred original Precambrian foliations, and all K-Ar ages are Miocene. Complications in Rb-Sr and zircon chronology are evidence of a vague pre-history. The completeness of overprinting is immediately significant in terms of Precambrian polymetamorphic belts.

The high-grade middle(?) Proterozoic rocks are in thrust contact with overlying Eocambrian greenschists. These, in turn, have non-metamorphosed Lower Palaeozoics thrust over them. This relationship is consistent throughout the Himalaya and it is puzzling why the high-grade metamorphism is confined to the previously metamorphosed basement (see Gansser, 1964). It could just be a depth factor, but is certainly significant, again, to Precambrian polymetamorphic belts.

Below the Main Central Thrust the metamorphic grade decreases downwards, from kyanite-sillimanite to, finally, low greenschist many kilometres below - the famous reverse metamorphism of the Himalaya. There is abundant evidence that it cannot be explained structurally, by recumbent folds, nappes, etc. In Le Fort's model (1975), underthrusting beneath the MCT resembles subduction. A cold slab passes down beneath the thick (20 km +) already hot slab above, which heats the rocks below from the top down - the reverse metamorphism. This is accentuated by upthrusting of the overlying block. Pressure release in the rising hot sheet above provides conditions for partial melting, confining the granites to the upper sheets. This reverse metamorphism may be common in older belts, but its recognition is difficult without the clear height control of the Himalaya.

PLATEAU UPLIFT

History of uplift

Soils, palaeokarst, planation surfaces, lake deposits, clay minerals, *Hipparion* vertebrate fauna, and palaeobotany all show that at the end of the Pliocene the Tethys Himalaya and Qinghai-Xizang (Tibet) Plateau had a subtropical warm moist climate and were no more than 1000 m high, and the Himalayas did not form a barrier to either animals or weather. Almost all of the uplift to the present elevation (4500-5000 m) has occurred in the 1 million years since end-Pliocene. Some areas are still rising at 1 cm/year (Li Jijun et al., 1979).

Indications are that a similar climate persisted back into the early Tertiary, although there were local faulted basins and ranges. The Kangdese-Nyainqentanghla and Tanggula ranges may have been uplifted to 1500-2000 m at times during Oligocene-Miocene.

Crustal Structure

Several seismic studies, of different types of earthquake waves or of controlled explosions, all identify 5 or 6 crustal layers, and a very thick crust containing a low-velocity layer, beneath the Tibet Plateau.

A 450 km long explosion profile (Fig. 5), of shots detonated in lakes, shows a different crustal structure north and south of the Yarlung Zangbo Suture Zone, with a sharp boundary between them. To the north the crust is 70-73 km thick, decreasing gradually northwards, and the 10 km-thick low-velocity layer (5.67 km/sec) is about 45 km deep. South of the Suture Zone, the crustal thickness decreases from 68 km to 45 km, beneath the Ganges Plain. The crest of the High Himalaya has not yet attained isostatic equilibrium; isostatic anomalies of up to + 150 mgal occur. Gravity studies essentially support this structural model. The structure beneath the crest of the High Himalaya differs significantly from earlier data by Qureshy (1971).

Earthquake epicentres indicate present-day north-dipping thrusts beneath the Himalaya foothills, and south-dipping (50°-70°S) faults beneath

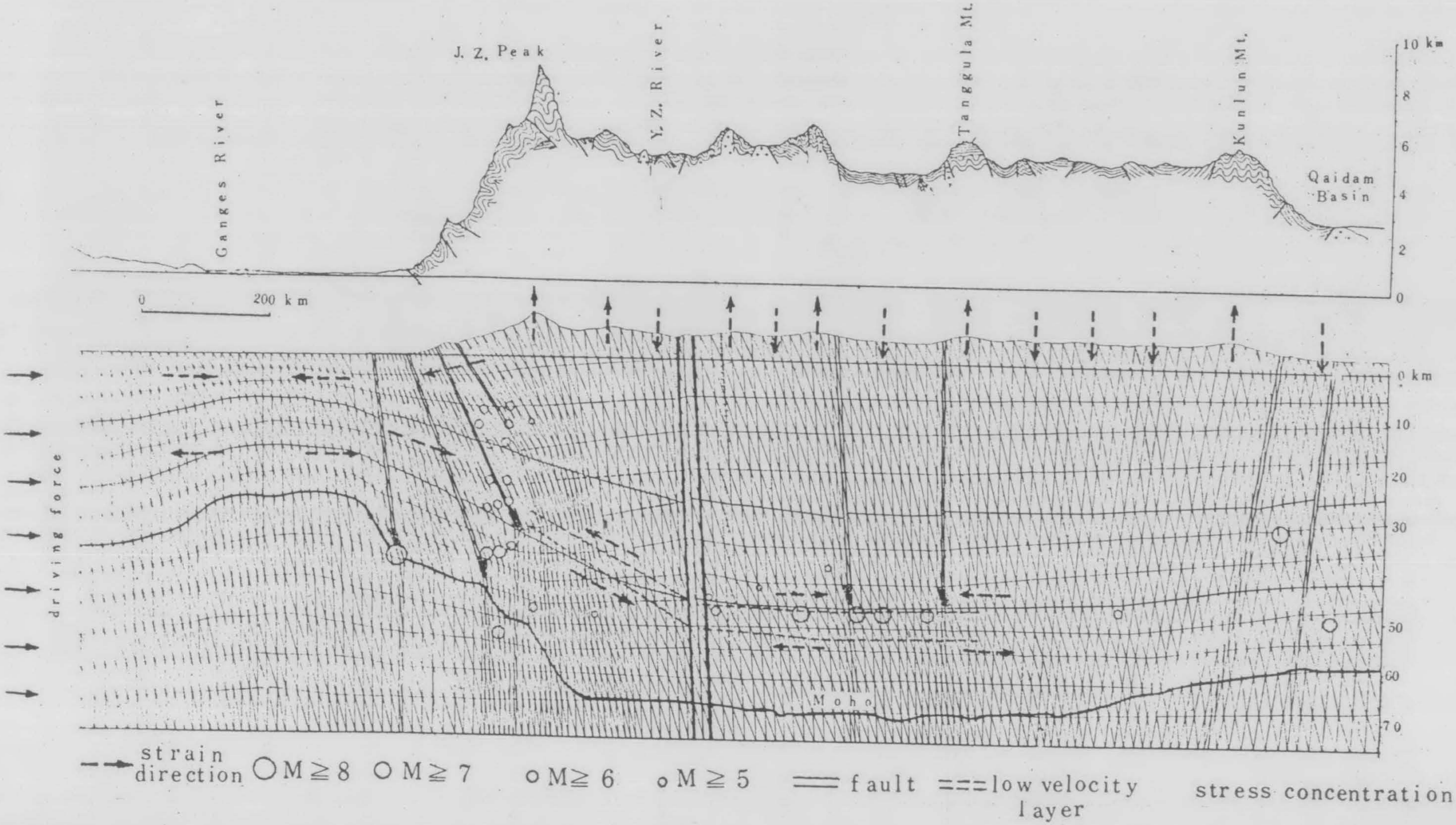

Figure 5. Simplified tectonic and crustal profile across Qinghai-Xizang (Tibet) Plateau (Loo Huan-yen et al., 1980; using seismic profile of Teng Ji-wen et al., 1980).

the Kunlun Mountains. A poorly-defined fault dips 65^{o}-75^{o} southwards from the Yarlung Zangbo Suture Zone, and aeromagnetic data indicates a similar attitude for the ultrabasic rocks there. A layer of epicentres follows the low-velocity layer, and most large earthquakes are concentrated above the low-velocity layer or at its ends.

Stress analyses show the Plateau under compression, in a NE-SW direction and, locally at the margins, perpendicular to the margins. This is reflected in the basinal profile of the Plateau surface. Surface faults in the interior of the Plateau indicate east-west tension.

Palaeomagnetism

Several published studies of palaeomagnetism and ocean-floor lineaments trace the drift of India towards Eurasia (e.g. Le Fort, 1975; Klootwijk, 1979; Powell, 1979). Generally accepted figures show convergence of more than 100 mm/yr between Late Cretaceous and collision; a slowing down and change in direction at collision; then convergence again at 50 mm/yr since collision. Implicit in these figures is the conclusion that, since the Eocene/Oligocene collision (40-50 m.y. ago), the Indian and Eurasian continents have converged about 2500-3500 km (Molnar and Chen, 1978); this must have been taken up by intracontinental deformation (Molnar and Tapponnier, 1975) (c.f. 500 km of crustal shortening in Himalaya; Gansser, 1974).

Of even greater significance is recent data on a Late Cretaceous-Early Tertiary pole from rocks within the Kangdese-Nyainqentanghla Fold System (i.e. since the block was attached to Eurasia) (Xiangyuan et al., 1977; reported by Molnar and Chen, 1978; Zhu Zhi-wen et al., 1980). This data shows, firstly, that the Kangdese-Nyainqentanghla block was separate from India at that time (Zhu Zhi-wen et al., 1980). More importantly, the data also shows that there has been 2000 km of convergence between the Kangdese-Nyainqentanghla block and the main part of Eurasia since Cretaceous (Molnar and Chen, 1978); this convergence must involve intracontinental deformation north of the Yarlung Zangbo Suture Zone (Molnar et al., 1980).

Origin of uplift

There is almost universal agreement that the uplift is related to thickening of the crust, although some authors ascribe varying importance to compression. Several calculations show that the Plateau interior is in isostatic equilibrium. Finite element analysis shows that gravitational variations in body forces alone can produce the observed elevations. Perhaps compression is only significant at the margins (e.g. Himalaya), where thrusting is still active and isostatic equilibrium has not been attained.

The crustal thickening has been related to the crustal shortening since collision. There are two main models (Fig. 6).

The upper model (Le Fort, 1975) follows that of Dewey and Burke (1973). After collision the crust beneath the Himalayas is thickened by underthrust slabs, progressively migrating from the Yarlung Zangbo Suture to Main Central Thrust, then to the Main Boundary Thrust. North of the Yarlung Zangbo Suture Zone, the crust beneath the Plateau is thickened during shortening by ductile creep at depth and fracturing and upright folding at shallower levels, accompanied by rising geoisotherms, partial melting, etc (Dewey and Burke, 1973).

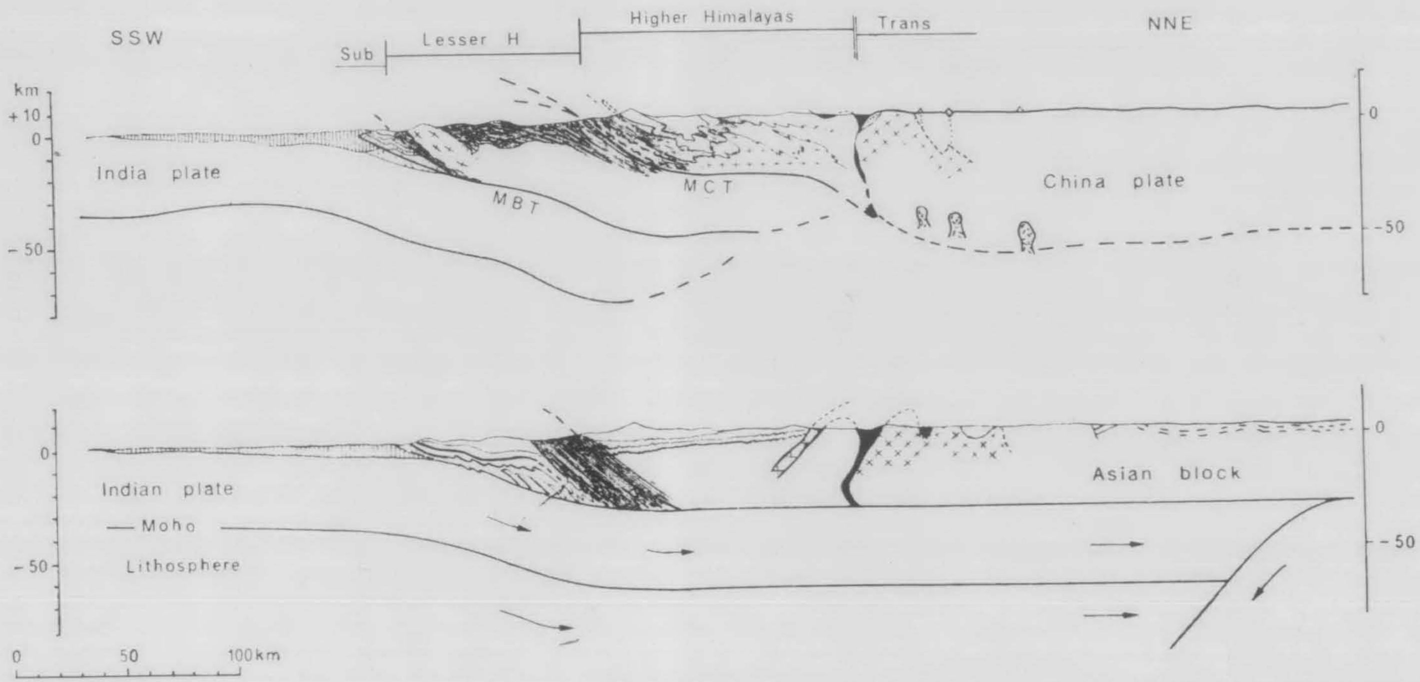

Figure 6. Present structure of the crust in the Himalayas. Above: according to Le Fort (1975).

Below: according to Powell and Conaghan (1973). (Le Fort, 1975).

The lower model (Powell & Conaghan, 1973) follows concepts of Argand (1924), Carey (1955), and Holmes (1965) that, after collision, a new subduction zone formed at the MBT, and Indian continental crust was thrust hundreds of kilometres beneath the Tibet Plateau.

Powell and Conaghans model is generally not favoured, because of density problems in subducting large amounts of continental crust (McKenzie, 1969). The majority opinion at the symposium seemed to accept the Dewey and Burke model.

One problem which remains unclear to me is why the uplift has occurred suddenly within the last million years, when the crustal thickening has been proceeding for 50 million years.

Discussion

Virtually all models of the Tibet Plateau presented to the symposium either assumed or interpreted crustal thickening by the Dewey and Burke model. Only L. Knopoff (California) concluded, from long-period surface waves across Eurasia, that the Upper Mantle under Tibet could be modelled in terms of shallow-angle subduction of ancient Indian shield beneath the Tibet Plateau. Frictional heating at the interface of the two crusts accounts for attenuation of Lg waves across Tibet.

The American analyses are based on a less detailed network of recording stations than available to the Chinese, and they apparently failed to identify the well-established low-velocity layer in the crust. For example, Teng Ta-liang (California), from Rayleigh and shear-wave analysis, identified a multi-layer crust, but a low-velocity layer at 90 km depth in the upper mantle. Chinese analysis of Rayleigh waves by Yao Zhen-xing et al. identified the low-velocity layer in the crust, but at a shallower depth than the explosion profile. It would seem to me that the explosion profile provides the best data so far.

Density problems in subducting continental crust (McKenzie, 1969) certainly place theoretical difficulties on Powell and Conaghan's model of crustal shortening. A present-day seismic/fault zone dipping southwards from the Yarlung Zangbo Suture Zone, with focal depths to 230 km (albeit, poorly defined by few epicentres) (Huan Wen-lin et al., 1980), seems clearly at variance with Powell and Conaghan's model. The deformation history of the Himalayas, progressively migrating southwards, is more compatible with Le Fort's model. Finally, the recent palaeomagnetic data which shows that most of the post-collision convergence has taken place within Eurasia by intracontinental deformation (Molnar et al., 1980) clearly eliminates the underplating model, although much more palaeomagnetic sampling is required for final confirmation.

Crustal thickening beneath the Himalaya by underthrust slabs is easy to understand. The crustal thickening north of the Yarlung Zangbo Suture Zone is ascribed to more obscure processes of compression and internal deformation.

Simple volume considerations show that a 50% crustal shortening (half the amount implied by palaeomagnetism) must double the crustal thickness (35 km to 70 km). Dewey and Burke (1973) consider that the thickening involves ductile creep at depth and fracturing at shallower levels; Burke et al. (1980) added upright folding and thrusting.

Geoisotherms are supposed to rise, and partial melting will produce magmas, all of which should cause crustal expansion. Finally, with the long history of continental accretion in Tibet, each phase of orogeny should produce its own crustal thickening, and so contribute to the total crustal thickness of the Plateau (e.g. Chang Cheng-fa et al., 1977; Hsu, 1980).

Northern Tibet has extensive Cainozoic volcanic rocks, of compositions compatible with Dewey and Burke's model. Early reconnaissance descriptions of northern Tibet implied very little deformation of Jurassic and younger rocks, and so are incompatible with crustal shortening. Recently, however, thrusts have been discovered in northern Tibet, and overthrusting of tectonic units is postulated as a major factor in crustal shortening and thickening in Tibet (Chang Cheng-fa & Pan Yu-sheng, 1980). Seismic velocities indicate crustal temperatures higher than normal, and southern Tibet is a major geothermal area, 2500 km long.

Molnar and Tapponnier (1975) have shown that much of the deformation north of the Himalaya can be accompanied by strike-slip faulting within Asia, reducing the amount of shortening across Tibet itself to a reasonable figure. Thermal modelling of a compressing plate (Zhu Bing-quan, 1980) indicates that magma generation should move from the mantle to crust with crustal thickening, and produce the observed variations in granite compositions. Uplift rates compatible with those observed are also predicted.

Dewey and Burke predict the development of a layered crust. The low-velocity layer is observed to be a loci of deformation and shearing, and possibly a source of partial melting. Leo Huan-yen et al. (1980) show experimentally that it could be derived from mechanical weakening by dehydration and lattice breakdown of minerals, while the shear movement is the source of its heating.

Much more data is needed from the main plateau region, but the observations so far seem compatible with the Dewey and Burke model for thickening the crust of the Plateau.

Isostatic uplift of the thickened crust, perhaps with addition of heating and thermal expression, are generally acknowledged as the origin of uplift of the Plateau and Himalaya (e.g. Chang Cheng-fa & Pan Yu-sheng, 1980), without adequately explaining why it was so much more rapid during Quaternary. Some people have ascribed varying degrees of compression, but others confine these effects to the margins. Leo Huan-yen et al. (1980) show by finite analysis that the Moho topography produces lateral density contrasts such that the gravitational variation in body force alone can produce the isostatic adjustment and observed plateau topography. Adding compression by India plate movement produces very little displacement beyond the collision zone.

Combining this analysis with observed active thrusting beneath the Himalaya and Kunlun Mountains, it is easy to see why these ranges are higher than the Plateau proper, and why the Himalaya is out of isostatic equilibrium. The accelerated uplift of the Himalaya in Quaternary may have been triggered by excessive thickening by underthrusting of the MBF (Fig. 6); a sort of threshold thickening.

It remains difficult to see why isostatic uplift north of the Yarlung Zangbo Suture Zone should have increased so much during Quaternary, when convergence and hence crustal thickening has been progressive since Miocene. Data is certainly more sparse there, and perhaps the palaeoclimatic criteria which have been used to estimate altitude reflect rainfall, and hence the Himalaya rain shadow, more than temperature (altitude). Some data imply elevations of the order of 2000 m in the Kangdese and Tanggula Ranges during Oligocene-Miocene, but 1000 m again at end Pliocene. Perhaps the process has in fact been more progressive, but culminated in Quaternary as convergence finally increased crustal thickness to its present threshold level.

RELEVANCE TO PRECAMBRIAN STUDIES

Most Precambrian mobile belts are incompletely exposed, because of widespread cover by younger sedimentary basins, so care must be exercised in basing interpretations on the failure to find certain rock types. Perhaps the critical zones, such as ophiolitic suture zones and other oceanic rocks, may be the very zones, because of tectonic instability, which become most readily covered. In Tibet the highest range (Himalaya) is continental rocks, and the suture zone is comparatively low.

Most Proterozoic mobile belts appear to be entirely ensialic, so processes of intracontinental orogeny have been invented to explain them. However, almost all the rocks exposed in the Himalayan Fold System are ensialic, and many of the sediments are of platformal type. Exposures of oceanic rocks are confined to a very narrow, and discontinuous belt.

The Yarlung Zangbo Suture Zone, one of the great ophiolite belts of the world, is the remains of an ocean thousands of kilometres wide, yet ophiolites are only preserved in a discontinuous belt less than 15 km wide; outside Tibet they are even less continuous. Classic high-pressure minerals are rare; so far glaucophane has only been confirmed outside Tibet.

At depth, the common erosion level in Precambrian belts, the ophiolites could well be replaced by a cryptic suture (e.g. Figs 3, 4, 6).

We did not see many calc-alkaline volcanics, and only at high structural levels in the Kangdese Range where they could be quickly eroded. On the other hand, Tibet contains large volumes of plutonic rocks of both mantle and crustal derivation, and commonly mixed in composite batholiths. Surely many of the apparent geochemically anomalous Proterozoic rocks can be explained by the complexity of processes provided by collision and crustal thickening.

The intensity of the Miocene metamorphism and its complete overprinting of Precambrian source rocks, now exposed right at the crest of the High Himalaya, is an impressive demonstration that collision does produce the types of metamorphism seen in Proterozoic mobile belts. The Kohistan Sequence of northern Pakistan, postulated as the roots of an ancient island arc, has rocks up to pyroxene granulite facies (Tahirkheli et al., 1979). Many of the complex distributions of metamorphic grades in ancient belts may be explained in terms of the famous Himalayan reverse metamorphism. The high heat flows produced in the region is consistent with the low-pressure metamorphic facies series common in Proterozoic terrains. All of the tectonic blocks across the Tibet Plateau have undergone multiple orogeny, and so should display polymetamorphism at depth.

The principal evidence used against Proterozoic plate tectonics is lack of evidence of lateral displacements between crustal blocks. Sometimes this is based on correlation of sequences into and across belts, but this is always fraught with difficulty, in the absence of palaeontological or other evidence of precise age equivalence. Precambrian palaeomagnetic data is also questionable at this stage, even amongst palaeomagnetists. Although available data commonly indicates consistent evidence against displacements, Precambrian polar wander curves are still very poorly defined, new data commonly reveals major errors (e.g. Idnurm & Giddings, 1980), identical data is subject to diametrically opposed interpretations, and most agree that the data certainly cannot eliminate movements of the order of 1000 km. The observed patterns of Proterozoic tectonic belts indicate that smaller crustal blocks were involved than those of Mesozoic-Cainozoic plate tectonics. It would seem, therefore, axiomatic that smaller plate displacements may be involved, increasing the difficulty of palaeomagnetism in identifying them.

Major strike-slip faults, recumbent folds, thrusts, and nappes are all common in Precambrian terrains, demonstrating horizontal displacements, convergence, and crustal shortening. Until it can be conclusively proved that significant horizontal plate movements have not occurred in the Precambrian, we should perhaps heed the conclusion of Burke et al. (1980) - "Zones of "reactivation" so commonly recognised in the Precambrian and mostly by thermal effects on isotopic systems, are readily accounted for by Tibetan-style collision-related orogenesis and magmatism. Ad Hoc non-actualistic models for such reactivation are unnecessary". However, an objective approach to Proterozoic data must be retained before the uncritical application of either plate tectonic models, or of more hypothetical models which lack demonstrated modern counterparts.

CONCLUSION

The success of the multidisciplinary Symposium on Qinghai-Xizang (Tibet) Plateau and excursion to southern Tibet exceeded all expectations.

The wealth of data obtained by scientists of the People's Republic of China from this important region is of major scientific importance.

The data presented to the Sym)osium, and the observations made on the excursion, are all consistent wi:h the popular theories of origin of the Himalaya and Tibet Plateau. The region is the product of alternating oceanic rifting and subsequent accretion of continental blocks to Eurasia throughout Phanerozoic, culminating in the Tertiary collision of the Indian Subcontinent with Eurasia. The great uplift of the Plateau is the result of isostatic adjustment to crustal thickening, produced by crustal shortening during intracontinental convergence.

The insight gained by personal experience of this magnificently exposed and diverse mountain belt has broadened my appreciation of the problems of Precambrian tectonics, and demonstrated that plate tectonic phenomena, and particularly Tibetan-style collision phenomena, may be more applicable to the Proterozoic than is commonly accepted.

Present non-actualistic models of Precambrian tectonism need critical examination.

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(a)

Appendix 1

A REVIEW OF THE MULTI-DISCIPLINED SCIENTIFIC RESEARCH ON THE QINGHAI-XIZANG PLATEAU BY CHINESE SCIENTISTS IN RECENT YEARS

Liu Tung-sheng   Sun Hung-lieh

Mr Chairmain, Comrades and Friends,

It is a great pleasure to meet here with the learned colleagues from 17 countries to explore the important problem on the "Formation and evolution of the Qinghai-Xizang plateau and its influences on the environment and human activities".

The upheaval of the Qinghai-Xizang plateau is an event of the greatest significance in Asia during the last several million years. The Plateau has fundamentally changed the natural landscape from what it had been, bringing about profound influences on the neighbouring areas, and drawing the attention of scientists from various fields. Most of the Plateau lies within the boundaries of China, starting from the Kunlun Mts. in the north to the Himalayas in the south and from the Karakoram in the west to the Meridional Ranges with great gorges in the east, covering an area of 2,400,000 km^2, almost ¼ of China's territory. It is the home of the Xizang nationality of the Chinese people who have well adapted to the unique environment, and have greatly improved their living conditions since liberation. It is clear, then that a thorough investigation of the Plateau will not only add to the treasury of scientific information, but also lead the way in making contributions to humanity.

(b)

The Academia Sinica, aiming at a summarization of all available data concerning the formation and evolution of the Qinghai-Xizang plateau as well as the formulation of a proposal concerning the management of natural resources and the protection against natural catastrophes, has been sponsoring since the 50s a number of expeditions to the Plateau, i.e. (1) the 1951-1952 expedition in geology, geography and agriculture of central and eastern parts of the Xizang Autonomous Region; (2) the 1959 expedition of Mt. Qomolangma (the first time); (3) the 1960-1961 expedition in geology, geography, biology and agriculture of central and southern parts of Xizang; (4) the 1958-1961 expedition in geography, agriculture and river conservancy of the eastern part of the Plateau, including the gorge district; (5) the 1964 expedition of Mt. Xishabangma; (6) the 1966-1968 expedition of Mt. Qomolangma (the second time); (7) the 1973-1979 expedition in geophysics, geology, geography, biology and agriculture of the whole Xizang; (8) the 1975 expedition of Mt. Qomolangma (the third time). One after the other, these multi-disciplinary expeditions amplify and intensify the understanding of the Plateau. The 1973-1979 expedition lasted longer with more disciplines than the other expeditions, when, for 7 years, over 50 disciplines were involved and over 400 scientists and technicians participated in the field work and a personnel of over 1,200 in the laboratory work. Based on the results of these expeditions, a series of "Monographs of the Qinghai-Xizang Plateau" including 32 volumes and a pictorial "Exploring the Secrets of the Roof of World" have been, or are being published in succession later this year.

(c)

In addition to the works by Academia Sinica, various institutes of geology, seismology, meteorology and agriculture have shared in the researches and have published a number of monographs; the journals of scientific societies have also published many papers on different topics of Qinghai-Xizang research.

Comrades and friends, allow me, now, to make a summary of the major achievements by the Chinese scientists, particularly since 1973.

(1) <u>A working hypothesis on the evolution of the Plateau, the mechanism of the upheaval, and on the characteristics of the different geophysical fields</u>

The Qinghai-Xizang plateau may be considered one of the best places to study the earth interior and the mechanism of crustal movement. The Chinese have made a commendable start in this respect through the researches in stratigraphy, paleontology, petrology, geothermics, geochemistry, geotectonics and geophysics. The fossils are extremely rich in the Plateau. Already 30 or more families totally 3,800 species have been discovered in recent years, comparing with only 300 species mentioned in literature prior to the liberation. According to paleontological and sedimentary informations, Xizang may be divided into 4 stratigraphic regions and 11 subregions, for each of which a complete stratigraphic profile has been established. The 4 regions are: 1) the Himalaya, 2) the Kangdese-Nianqengtanghla, 3) the Tanggla-Hengduan gorge district and 4) the Kokoxili-Kunlun. In the Himalaya region, fossils of *Glossopteris* and cold-water biota have been found in the late Paleozoic beds, while to the north of the Yarlungzangbo river, fossils of *Gigantonoclea* and warm-water biota have been found in the Permian formation. That means, the Yarlung Zangbo valley lies on an important boundary of paleontological significance.

(d)

Petrographic analysis shows that the granites of Xizang may chronologically be grouped into 3 belts: the Kangdese belt (120-70 m.y., belonging to I-type), the Lagui Gangri belt (50-30 m.y.), and the Himalaya belt (20-10 m.y. belonging to the S-type). A series of progressive changes exists in the 3 belts, with the result that from N to S, the alkali-feldspar coefficient increases, the An value in the plagioclase decreases, the differentiation index and K, Si contents increase and the Ti, Fe, Mg and Ca contents decrease, the distribution pattern of rare earth elements differs, and finally, the ratio of Sr^{87}/Sr^{86} increases from 0.704 to 0.747. Time and space distribution of granites indicates that the early magmatic activities originated partly from the remelting of the sediments atop the oceanic crust. Later, the collision and compression resulted in the remelting of the sial material of the continental crust and in the differentiation of magmatic pockets. The ophiolite belt which extends W-E for about 1,000 km along the S-bank of the Yarlung Zangbo has also been examined in petrographical details. This belt connects in the west, the ophiolite belt of Indus river and in the east, beyond the great river band, that at the Burmese border. The ophiolite might have emplaced sometime between Eocene and Miocene, accompanied by intense folds of flysch and by development of mélange and exotic blocks. The occurrence of ophiolites and a series of linear features associated seems to confirm that the composite structural line along the Yarlung Zangbo is suture zone between two plates.

The strong Himalaya movement is also echoed by geothermal phenomena. The greatest thermal belt of China's mainland occurs here starting from W. Ali, Xizang, down the Yarlung Zangbo valley, crossing the Meridional Mts., before joining the geothermal region of W. Yunnan. Altogether, there are about 600 hydrothermal areas, including 11 areas with explosions, 3 geysers and tens of boiling springs. According to the data of shallow drilling to a few hundred metres in the thermal field of Yangbajin, about 80 km NW of Lhasa, the geothermal gradient in the upper part of the crust averages to $2.9^{o}-3.5^{o}C/m$, which is about 100 times the average value of the whole crust. Chances are that the heat source of this thermal belt comes from some sort of shallow magmatic activities beneath the ground surface.

For the purpose of exploring the deeper structure in the crust and upper mantle, geophysical researches of different kinds have been initiated, such as seismology, gravimetry, paleomagnetism and magneto-telluric probing. Deep seismic sounding confirmed the layered structure and disclosed the existence of a low velocity layer in the crust. Paleogeomagnetic study revealed that the areas to the north and south of the Yarlung Zangbo valley belong to 2 different plates; to the north, the crust is about 70 km thick and to the south, about 50 km. The isostatic anomaly in the Qomolangma area is + 120 mg, indicating that the crust is over-compensated. But the uplift is still continuing. This is due to the compression effect caused by the pushing northward of the Indian plate.

All the above-mentioned phenomena suffice to show that the Qinghai-Xizang plateau and the Himalaya system are the products of the collision of the Indian plate with the Eurasian. The Himalaya system might have been completed between Miocene and Pliocene; but the *Hipparion* fauna found in Xizang implies that even in late Tertiary, the Plateau might not have exceeded 1,000 m in elevation. Strong upheaval at the end of Pliocene, with 3 successive lifts of large amplitude accelerated the rise. For the last 100,000 years since Pleistocene, a rise of 10 mm/yr has been estimated.

(2) <u>An explanatory description of the influences of the Plateau's upheaval on the environment, and an understanding of the characteristics, evolution and differentiation of the environment</u>

In the course of the Plateau's upheaval, there occurred at least 4 glacial periods separated by interglacial. In late Pleistocene, when the Himalayas have reached the great height, the warm wet monsoon was blocked to the south of the Plateau, resulting in cold aridity over Xizang. Permafrost appears, glaciers retreat, lakes dwindle and the uniqueness of the environment strengthens.

For many years, the Chinese scientists have systematically analysed the natural features, particularly their types, characteristics, distribution and modification due to the upheaval of the Plateau. Regarding meteorology and climatology, the existence of the atmospheric boundary of the Plateau makes its dynamic effect far exceed that of the actual area of the Plateau. The activities of the low vortices and the shear lines within the boundary, as well as the important influences of the South Asiatic High (at 100 mb) on weather and climate have been studied.

The intensity of heat source and sink of the Plateau have also been observed and calculated. The monsoonal phenomena over the Plateau, being a separated system from the ordinary monsoon over the lowlands, is motivated by the seasonal variation of heat source and the consequent change in the upper air circulation. In addition, the formation, development and maintainence of the circulation over the Plateau are simulated by both models and numerical experiments. Those phenomena may even affect the central Pacific and intrude into the Southern Hemisphere. The physico-geographer is of the opinion that the surface relief and its impact on the atmospheric circulation are decisive in differentiating the physical environment. The gradual worsening of hydrothermal conditions from SE toward NW is echoed by a vegetal change as spaced in the following zones: forest-meadow-steppe-desert. This zonation may be taken as a vertical expression of the horizontal zonality. By integrating the vertical with the horizontal zonation, 9 physical belts have been suggested within the Plateau each with its distinctive characteristics.

In line with local conditions, a tentative scheme has been made regarding the agricultural development. Thus, north of the Kangdese-Nianqengtanggulha range is best suited for yak and sheep raising and the Yarlung Zangbo valley for cultivation of winter wheat and Qingke (a kind of huskless barley). The upper limit of these 2 crops reaches respectively 4,200 m and 4,800 m, being the highest in the world. So far as cultivation is concerned, the Plateau tops all other croplands, thanks to its high intensity of radiation, long duration of growing temperature, favourable combination of light and warmth and adequate period for photophilous and cool-adapted crops to tiller and milk; hence the yield of winter wheat reaches as high as 13,000 kg/ha, being one of the highest in China today. In the forest belt from the south slopes of the Himalaya to the gorge district in East Xizang, the dark coniferous forests grow as far up as 4,100 m - 4,600 m, yielding 2,000 m^3/ha, a rare record in the world.

(3) An analysis of the flora and fauna, and the adaptation of plants and animals to the Plateau environment

The upheaval of the Plateau has retained, on the one hand, some ancient forms of the biota, while on the other hand, has induced the formation of new species. The Plateau has long been called the "Treasure House" of biological resources. Already 530 species of birds and 190 of mammals have been collected, 7 being new species and 11 new subspecies. This exceeds the total number of species recorded prior to the founding of New China. As to the insects, 100,000 specimens have been collected and 2,300 species so far identified. Among them there are 20 new genera, 400 new species and subspecies, about ¼ as many as the new species identified since the founding of New China. Furthermore, in SE Xizang, specimens of the order *Zoraptera* have been first recorded for China.

On the botanical side, the newly finished monograph The Flora of Xizang describes more than 5,000 species of higher plants, including several hundred new species and 5 new genera. Among plants, fungi, mosses and lichens, there are several new species discovered in the Plateau.

Based on the analyses of a great quantity of data, the zoogeographers, agreeing with the phytogeographers, reject the simple idea of taking Xizang as merely an ancient or a recent fauna. True, the scarcity of endemic genera of vertebrates indicates the relatively short history of evolution, but the 23 endemic species of birds and 44 of mammals verify their survival of the glaciation. The botanists observe that the Xizang flora has originated from the Meridional Ranges and have evolved during the uplift of the Himalaya. As in East Asia and North America, the Plateau is a centre of differentiation and evolution of some major species or species-groups in the north temperate zone.

Observations have also been made by the Chinese scientists regarding the adaptations of men and animals to the environment of the Plateau. The long dwelt inhabitants of the Plateau have been taken as an example in comparing with the lowland dwellers concerning their physiological changes and their adaptability to the high altitudes. An electrocardiogram of Ms. Pando, the well known Tibetan woman mountaineer, was taken by telemetry, when she was up Mt. Qomolangma in 1975.

Comrades and friends, looking back to our prevous work, I feel that we have only taken the first step in the long journey ahead of us. A good number of important problems, such as the nature of the major tectono-sedimentary belts, the stratigraphy in relation to the composition and evolution of the paleo-biota, the characteristics and dynamic system of the geophysical fields, the influences of the Plateau on the weather and climate in minor localities, the physiological and ecological adaptations as well as the genetic variations of the various plants and animals to the Plateau, the rational management of the natural resources and the measures taken in overcoming the unfavourable factors, all of these require further investigations.

We are, indeed, glad to see that more and more attention has been paid to the research work of the Plateau by the scientists all over the world. We know that numerous magnificent results have been achieved through insistent work by our science colleagues on the Himalayas, the Korakoram and vicinities. We shall listen to your lectures and reports with greatest interests. It is our sincere hope that this symposium will pave the way for constant exchanges of views and that, further cooperation will facilitate our researches in a common effort of making greater contributions to humanity.

Thank you for attention.