Revista Brasileira de Geociências 12(1-3): 65-73, Mar.-Set., 1982 - São Paulo

THE LOWER PRECAMBRIAN OF CHINA

CHENG YUQI*, BAI JIN** and SUN DAZHONG**

ABSTRACT The Lower Precambrian of China consists of Archean and Lower Proterozoic formations formed probably prior to *ca.* 1,800-1,900 Ma. They are exposed chiefly in the North China Platform.

Archean rocks are composed mainly of gneisses, granulitite and plagioclase-amphibolite of the amphibolite facies, with the lower part containing pyroxene-gneiss and granulite of the granulite facies. The parent rocks were not well differentiated sedimentaries and volcanics, forming two volcano-sedimentary cycles. During the Archean (before 2,500-2,600 Ma), the tectonic environment over an extensive area was quite uniform yet fairly active. Towards the end of Archean there prevailed median- to high-grade metamorphism often accompanied by rather intensive migmatization.

In the first Early Proterozoic epoch, a thick sequence of volcano-sedimentaries were accumulated in some marine troughs regarded as eugeosynclinal and developed on the Archean sialic basement, such as the Wutai Group. The protoliths were the rather widespread volcanics, the "semipelitic" and pelitic types and turbidites, mainly of greenschist facies and partly amphibolite facies, occasionally accompanied by migmatization probably not later than 2,300 Ma.

After that, a stratigraphic pile accumulated in the miogeosynclinal basins or troughs as represented by the Hutuo Group, and was composed of coarser clastics, pelitics and stromatolite-bearing Mg-rich carbonates which show rhythmic deposition. Their greenschist metamorphism probably occurred during *ca.* 1,800-1,900 Ma and this marked the end of the Early Precambrian history.

INTRODUCTION According to the recent opinion of many Chinese geologists, the Lower Precambrian of China consists of the Archean and Lower Proterozoic metamorphic formations, unconformably underlying the Upper Precambrian. They are composed of various kinds of protolithic rocks metamorphosed from low greenschist facies to granulites facies, older than *ca.* 1,800-1,900 Ma, and suffered other complicated changes throughout the prolonged geological history. They are exposed chiefly in the regions roughly lying between 30°N and 45°N latitude, especially in Northern China and the southern part of Northeastern China. The mineral resources found in these ancient rocks are numerous and varied, including ores of iron, gold, copper and others, and deposits of magnesite, talc, apatite, mica and some of the rare and dispersed elements, all being formed during the Early Precambrian, as well as different kinds of later endogenetic mineral deposits.

Since the submission of the paper on the Lower Precambrian of China for the Second All-China Stratigraphic Congress convened in 1979 (Yuqi *et al.*, 1982), some progress has been made in many scientific fields related to this aspect, particularly in geochronology. So that we are now in a better position to summarize their stratigraphic constitution, subdivision and correlation, age and geological history, as well as the characteristics of the geological setting of the formation of the original rocks concerned and the condition and degree of metamorphism and other geological modifications and transformations they have undergone.

The aim of the present paper is to describe the Lower Precambrian of China in a concise form. It contains the stratigraphic description of eight separate regions (Fig. 1) each characterized by certain salient geological features and the following brief synthesis regarding the stratigraphic correlation and certain evolutional characteristics.

SOUTHERN PART OF NORTHEASTERN CHINA

(Jilin and Liaoning, I, Fig. 1) It is to the south of 43°N latitude that the Lower Precambrian rocks of this region are well exposed, and thence extending almost continuously southwestward well over 700 km, till nearly to the end of the Liaodong Peninsula. They are subdivided by an unconformity into the lower Anshan Group and the upper Liaohe Group.

Rocks of the Archean Anshan Group are of great thickness, probably over 9,000 m, and exposed mostly in a northern belt extending from the Anshan-Fushun-Tieling region east-northeastward chiefly along the Longgang mountain range, and in a southern belt near the coast of the peninsula stretching for a certain distance in a similar direction. The rock-types frequently seen in the lower part are biotite-plagioclase-gneiss and hornblende-biotite-plagioclase-gneiss with amphibolite intercalations. Some pyroxene-granulites have been recently discovered in the last few years. While the amount of biotite-granulitite[1] and various

[1] Corresponding to the "Pepper-and-salt Moine" type of quartz-feldspar-granulites of Scotland. In order to distinguish the Moine-type "granulite" from the granulite facies "granulite" of higher grade of metamorphism, a new name "granulitite" was provisionally proposed by the senior writer and his colleagues in 1972 (Yuqi *et al.*, 1973) for the former and other rocks showing similar structure, texture and degree of metamorphism

* Chinese Academy of Geological Sciences, Beijing, China
** Tianjin Institute of Geology and Mineral Resources, Chinese Academy of Geological Sciences, Tianjin, China

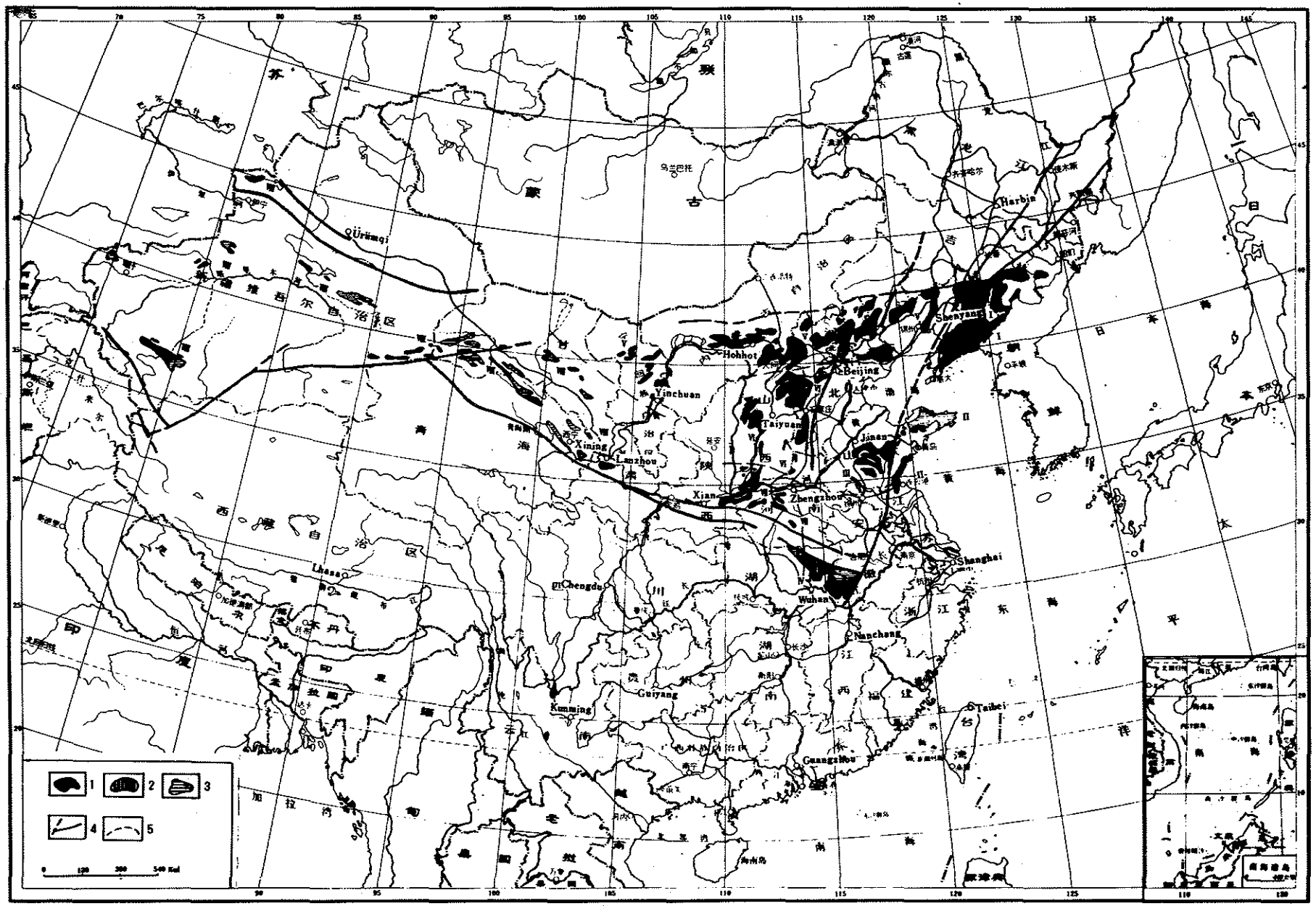

Figure 1 – Sketch map showing the distribution of the Lower Precambrian: I. Southern part of Northeastern China (Liaoning and Jilin); II. Eastern part of Peninsula Shandong and Southeastern Shandong; III. Central and Western Shandong; IV. Huaiyang Region; V. Yinshan and Yanshan Region; VI. Taihangshan-Wutaishan-Luliangshan Region; VII. The Northern slope of Eastern Qinling Range; VIII. Northwestern China; 1. Archean; 2. Lower Proterozoic; 3. Archean or Lower Proterozoic uncertain; 4. Fault; 5. Region boundary

hornblendic types, including amphibolite, increases in the upper part, which is also often characterized by the presence of quartz-sericite (muscovite) schist and sericite-chlorite schist or leuco-granulitite and tourmaline granulitite. The banded iron formation (BIF) is comparatively developed. A few intercalated layers or lenses of marbles are locally present.

Most of the rocks are of the amphibolite facies and only a portion of the lower part belongs to the granulite facies, while a part of the uppermost horizon may lie within the domain of the greenschist. They often show evidence of being migmatized.

The original rocks of the lower part were mostly "semi-pelitic" types[2] with volcanic intercalations mostly of basic composition, those of the middle part, chiefly "basic" types[3], and those of the upper, dominantly silty types.

The counterpart of Anshan Group in Jilin Province is the Longgang Group.

The results of isotopic age determinations by various methods[4], up to 1979 have shown that the rocks of the Anshan Group had undergone at least two periods of regional metamorphism and migmatization, at about 3,000 and 2,500 Ma, respectively. Further studies on zircon from the granite gneiss invading the ancient metamorphics give an additional Pb-Pb isochron age of 2,635 Ma, and a U-Pb age of 2,632 Ma on a concordia diagram[5], and by U-Pb, Pb-Pb and Rb-Sr isochron methods yield a new value of 3,100 Ma[6] for Anshan Group, being considered as the age of its formation by some geologists.

Exposures of the thick sequence, probably over 10,000 m, of the Lower Proterozoic Liaohe Group and its equivalent formations are found mainly in a central belt of the Lower Precambrian terrain of Jilin and Eastern Liaoning. Generally the common rock types in the lower part are pelitic schists (and or phyllites), leuco-granulitite and other granulititic types and some marbles, characterized by the association of tourmaline granulitite beds and also volcano-sedimentaries partly of keratophyric affinity. In the middle or lower-middle part, magnesian marbles with or without stromatolites are frequently found, often accompanied by pelitic intercalations. The dominant rocks in the upper or upper-middle are pelitic rocks of different degrees of metamorphism, partly interbedded by marble or even quartzite. The rocks belong either to the amphibolite or to the greenschist facies. They are usually only partly migmatized.

In Jilin, the rock formations corresponding to the Liaohe are subdivided into the lower Ji-an Group and the upper Laoling Group. In the districts of Kuandian, Tonghua, Xiuyan, etc., the lower part of Liaohe Group has been separated out and named as Kuandian Group by some geologists and this is probably to be correlated with the Ji-an Group just mentioned.

The K-Ar age of metamorphism and migmatization of the Liaohe Group has been reported to be about 1,800 Ma and 1,750 Ma (Yuqi *et al.*, 1973). Recent studies give an age of *ca.* 2,040 Ma by various methods for the Liaohe[7].

Some geologists are of the opinion that a part of the Liaohe Group is Upper Precambrian in age instead of the upper part of Lower Precambrian.

EASTERN PART OF SHANDONG PENINSULA AND SOUTHEASTERN SHANDONG PROVINCE (II, Fig. 1) The Lower Precambrian formations of this region are cropped out to the east of the Tancheng-Lujiang fault zone. Those of the eastern part of Shandong Peninsula show some resemblance to these of Liaoning. The lower Jiaodong Group is a colossal sequence of gneiss, granulitite and amphibolite, containing also marble and graphite-bearing rocks, most of which are of amphibolite facies and partly migmatized. The original rocks were chiefly fine clastic sediments with calcareous beds, probably comprising also some basic volcanics and pyroclastics. It is intruded by a pegmatite showing a K-Ar date of 1,715 Ma (Yuqi *et al.*, 1973). The upper Fenzishan Group of much less thickness is usually unconformably underlain by the Jiaodong and overlain by the Upper Precambrian Penglai Group. It consists mostly of pelitic schists and marble of the greenschist facies.

Those of the southeastern part of Shandong province have been regarded as belonging to the Jiaodong Group and are composed chiefly of mica-potash-feldspar gneiss, biotite-granulitite and leuco-granulitite with some marble.

CENTRAL AND WESTERN SHANDONG (III, Fig. 1) The Lower Precambrian rocks are exposed to the west of the Tancheng-Lujiang fault zone and belong to the Archean Taishan Group. It is a tremendous succession, probably over 10,000 m, of biotite-plagioclase-gneiss and hornblende-plagioclase-gneiss and also plagioclase-amphibolite and biotite granulitite, metamorphosed to amphibolite facies probably of the moderate-temperature, moderate- to low-pressure facies series and partly further migmatized to various degrees. The rocks are subdivided into four formations, with the lower two characterized by protolithic fine siltstones partly of greywacke nature and basic volcano-sedimentaries, the third one, viz., the Yanlingguan Formation, marked by the presence of subaqueous and even subaerial basic lavas and volcano-sedimentaries prior to metamorphism, and the fourth Shancaoyu Formation, by fine siltstone partly of greywacke character.

The biotite from the granulitite and gneiss show an average K-Ar age of 2,380 Ma (Yuqi *et al.*, 1973). The Rb-Sr

[2]Mostly fine sediments of silt grade, partly probably of greywackes composition or mingled with tuffaceous materials

[3]Basic lavas and pyro-clastics with or without sodic affinity, with associated intrusions, sometimes including iron-rich marly sediments

[4]The determinations were made by the Guiyang Institute of Geochemistry and Institute of Geology, Academic Sinica and other institutions (Yuqi *et al.*, 1982)

[5]A paper by Wu Jiahong and Piao Kuangao, submitted to the Symposium on the Early Precambrian metamorphosed volcano-sedimentaries held in Shenyang, China, in Oct. 1981 (henceforth abbreviated as "SEPCMV", Shenyang, 1981)

[6]Determined by the Guiyang Institute of Geochemistry, Academic Sinica (Yuqi *et al.*, 1982), and Yuwei *et al.*, (1981)

[7]A paper by Tao Quan, submitted to "SEPCMV", Shenyang, 1981

isochron age of the first stage migmatization suffered by the said group is 2,586 Ma[8] and the K-Ar age of the second, 2,160 Ma.

HUAIYANG REGION (IV, Fig. 1) In the Huaiyang region, within the rugged terrain of Dabieshan, Dahongshan and Tongbaishan mountains, the Lower Precambrian formations extend roughly in a NW-SE direction for about 400 km in the borderland of Anhui, Henan and Hubei provinces. Those exposed in the eastern part have been subdivided in ascending order into three units, *i.e.* Dabie Group, Taihu Group and Susong Group, with an unconformity lying between the former two. In Hubei, the Dabie Group is unconformably overlain by the Hong-an Group which is approximately the counterpart of the Taihu Group. The former consists chiefly of hornblende-plagioclase-gneiss and biotite--hornblende gneiss with intercalated granulitites and some marbles of the amphibolite facies, derived from basic volcanics, tuffaceous siltstone, greywacke, etc., while the latter comprises mainly muscovite-quartz schist (with or without albite) and also epidote-actinolite schist, etc., of the greenschist facies, being mostly metamorphosed siltstone and tuffaceous siltstone with some spilitic and keratophyric volcanics. So far only one U-Pb isotopic determination for zircon from the Dabie Group gives an age of 3,120 Ma[9] indicating that the rocks had been formed before 3,000 Ma. All the K-Ar isotopic age data lie within the time span from Middle Palaeozoic to Late Mesozoic and probably represent modified values of the original metamorphic ages.

YINSHAN-YANSHAN REGION (V, Fig. 1) The Lower Precambrian rocks of the region are distributed mostly within the limit of 40° to 42°N latitude. They extend from 103°E longitude eastward to 121°30'E for a distance of about 1,700 km, including the Alashan region and Yinshan Range in the west and the Yanshan and neighbouring mountains in the east. They are generally divided into three stratigraphic units.

1. Yinshan region The lower Sanggan Group of Archean age has recently been subdivided into a lower Jining Group and upper Wulashan Group. The former with a thickness probably over 10,000 m, is exposed mainly to the east of Huhhot, Nei Monggol. Its lower part consists chiefly of granulites and gneisses of the granulite facies derived from "basic" types and also "semipelitic" rocks. The middle part contains gneisses and granulitites of the amphibolite facies of pelitic and acid to intermediate volcanic origin, with some quartzite and marble. The upper portion is characterized by the dominance of marbles of the amphibolite facies. Most of the rocks have been migmatized to a greater or less degree. Among the sources of U-Pb and K-Ar age determinations of various minerals both from the metamorphic rocks and the pegmatite, U-Pb date of 2,359 Ma of an orthite sample from pegmatite gives the highest value. The Wulashan Group occurs mostly in the western part of this region and is also of great thickness, probably even thicker than the Jining Group. It consists mostly of gneisses, granulitites of pelitic and intermediate to basic volcanic origin with some marble and quartzite. Most of the rocks are of amphibolite facies and often migmatized, while those of the lower part may belong to the granulite facies.

The middle Sanheming Group which overlies the Wulashan Group with an uncertain contact relation, is of many thousand metres thick and correlated with the Lower Proterozoic Wutai Group of Shanxi described below. It consists mostly of plagioclase amphibolite, epidote-actinolite schist, chlorite schist, mica-albite schist, interbedded with biotite granulitite and taconite. The rocks are mainly of basic volcanic origin with "semipelitics", usually of greenschist facies and partly of amphibolite facies. They are only locally migmatized and intruded by Early Precambrian gneissic granites, and also pegmatites corresponding to 1,700-1,900 Ma dates.

The so called Erdaowa Group of much less thickness (Yuqi *et al.*, 1982) formerly considered to be equivalent to the Sanheming Group, has recently been redefined more strictly, but has proved to be lying unconformably on the latter. It begins with a conglomeratic base and consists mainly of pelitic types.

Unconformably underlain by the Erdaowa, the upper Majiadian Group, is of limited thickness and distribution. The lower part shows an upward succession of metamorphosed conglomerate and sandstone, phyllite, slate and slightly metamorphosed intermediate to acid volcanics with marble lenses, while the upper consists of different types of stromatolitic marbles, thus presenting a fairly complete cycle of sedimentation yet with phenomena of local rhythmic deposition. The rocks are also invaded by Early Precambrian gneissic granite intrusions. Both this and the Erdaowa Group may be correlated with the Hutuo Group of Shanxi.

2. Yanshan region The Lower Precambrian formations of this region formely known as the Sanggan Group, have been subdivided by many geologists in an ascending order into three groups: Qianxi Group, Dantazi Group[10] and Zhuzhangzi Group.

But the authors prefer to recommend the essentially successive sequence as worked out in 1979, in the eastern section of this region in eastern Hebei Province (Fig. 2), which consists, of the following four units, in ascending order:

1) QIANXI GROUP. In the strict sense, with a thickness over 2,700 m, roughly corresponds to the lower part of Qianxi Group" mentioned above. It may be correlated to the Jining Group of the Yinshan area, and is composed chiefly of hypersthene and or diopside granulites, gneisses, plagioclase amphibolites and pyroxene-bearing BIF. The rocks, being derived from basic to intermediate-acid volca-

[8]Isotopic determination made by the Institute of Geology, Chinese Academy of Geological Sciences (Yuqi *et al.*, 1982)

[9]A paper by Tao Quan, submitted to "SEPCMV", Shenyang, 1981

[10]Also called Luanxian Group recently by Qian Xianglin

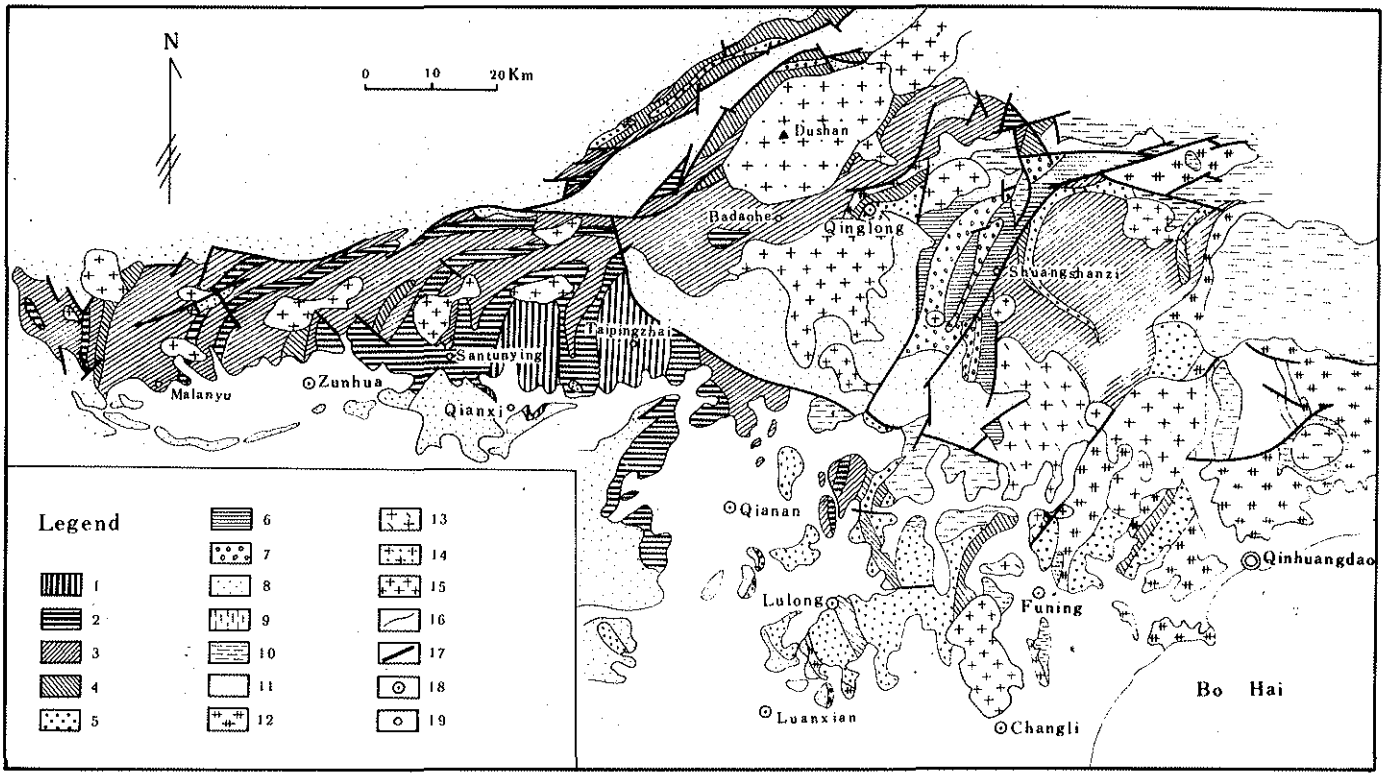

Figure 2 — Geological map of the Archean and Lower Proterozoic of eastern Hebei. ARCHEAN Qianxi Gr.: **1** *Shangchuan Fm.*; **2** *Santunyin Fm.*; Badaohe Gr.: **3** *Wangchang Fm.*; **4** *Wanzhangzi Fm.*; **5** *Sanmendian Fm.*; *LOWER PROTEROZOIC* **6** *Shuangshanzi Gr.*; **7** *Qinlonghe Gr.*; **8** *Middle and Upper Proterozoic*; **9** *Palaeozoic Erathem*; **10** *Mesozoic Erathem*; **11** *Cenozoic Erathem*; **12** *Migmatitic granite*; **13** *Amphibole-bearing migmatitic granite*; **14** *Proterozoic granite*; **15** *Mesozoic granite*; **16** *Geological boundary*; **17** *Fault*; **18** *County*; **19** *Town*

nics and volcano-sedimentaries, belong to the granulite facies, and have mostly been further migmatized. Isotopic ages of over 3,000 Ma have been obtained by K-Ar, Rb-Sr isochron and Pb-Pb isochron determinations[11] during the last seven years.

2) BADAOHE GROUP. Also of Archean age, and with a thickness of about 7,200 m, it contains the upper part of the former "Qianxi Group" and lower part of the Dantazi Group, and is the counterpart of the Wulashan Group of the Yinshan region. It is composed mainly of plagioclase--amphibolite and biotite-granulitite, with some pyroxenite and amphibolite in the lower horizon, containing actinolite- or cummingtonite-grunerite-bearing BIF in the upper part. Most of the original rocks were basic volcanics and "semipelitic" types, and underwent amphibolite facies metamorphism and migmatization. The recently reported Rb-Sr whole rock isochron date of 2,380-2,520 Ma[12] may indicate its metamorphic period.

3) SHUANGSHANZI GROUP. It comprises the middle-upper part of the Dantazi Group and part of the Zhuzhangzi Group. It is about 3,300 m thick and separated from the Badaohe Group by a tectonic disharmony which may represent an unconformity, and considered as the first formation of Lower Proterozoic and corresponding to the Sanheming Group of the Yinshan Range. The rocks are largely of plagioclase amphibolite still preserving pillow structure and two-mica-granulitite with graded bedding, interbedded with amphibole-chlorite schist, phyllite, micaschist and some cummingtonite-bearing BIF in the lower part, derived from basic to acidic volcanics and arkosic, "semipelitic" to pelitic types, metamorphosed to low grade amphibolite facies.

The whole rock Rb-Sr isochron age of metamorphism of the rocks is 2,400 Ma[12].

4) QINGLONGHE GROUP. Being over 1,350 m thick, and unconformably overlying the Shuangshanzi Group, it contains a portion of the Zhuzhangzi Group and may be correlated with the Majiadian Group of Yinshan, and assigned an Early Proterozoic age too. The base of this group is made up of meta-conglomerates and garnet-bearing micaschist. Above these there are biotite and/or muscovite granulitite and garnetiferous two-mica-quartz-schist with intercalated cummingtonite-magnetite quartzite. They are greenschist facies metamorphics derived from pelitics and turbidite-like sediments. Dating by the Rb-Sr isochron method gave an age of 2,390 Ma[13] indicating the time of metamorphism.

[11]Determinations made by the Institute of Geology, Academia Sinica, and by the Institute of Geomechanics and Institute of Geology of the Chinese Academy of Geological Sciences (Yuqi *et al.*, 1982)

[12]A paper by Sun Dazhong *et al.*, submitted to the Second All-China Stratigraphic Congress, 1979

[13]Determined by the Institute of Geology, Chinese Academy of Geological Sciences, 1982 (oral communication by Shen Qihan)

TAIHANGSHAN - WUTAISHAN - LULIANGSHAN REGION (VI, Fig. 1) Two belts of the Lower Precambrian rocks are exposed in this region. The first one stretches from 40°N latitude south-southwestward along the borderland of Shanxi and Hebei provinces to 35°30′ N, constituting the major part of the Taihangshan mountain range. The second branch off from northern section of the first in a southwestward direction till near 111°E longitude, 36°N latitude, including the mountainous country of Wutaishan, Luliangshan and other mountains in Shanxi.

There are three stratigraphic units showing unconformable contact with each other, and they, in turn, are unconformably overlain by different members of the Upper Precambrian. The oldest one generally known as the Fuping Group, is of great thickness, probably over 10,000 m, and found in different parts of Taihangshan and Luliangshan where it is known as Jiehekou Group. It is composed mostly of different types of gneisses and a variable amount of marbles, granulitites, etc, of the amphibolite facies, locally with rocks of the granulite facies. The parent rocks were mostly of "semipelitic" composition, including also some pelitic, arkosic, carbonate and "basic" types. At many places, the rocks have been rather intensely migmatized. There is yet another stratigraphic unit under the name of Longquanguan Group, up to 5,000 m thick, which is locally present between the Fuping and the overlying Wutai Group with unconformable contacts both above and below. It is composed chiefly of "semipelitic" to pelitic granulitites, schists and gneisses of amphibolite facies, and invaded by a Pre-Wutai granitic body, with an U-Pb isochron age of 2,560 Ma[14] on zircon. Hence both the Fuping and Longquanguan Groups are of Archean age.

An older age of 2,800-2,830 Ma[14] has been given by the same method on detrital zircon from the lower horizon of Fuping, referred as the possible lower age limit of its formation by some geologists. A biotite sample from the upper part of Fuping shows a K-Ar date of 2,310 Ma which is probably a modified value of the original metamorphic age. Besides the Fuping rocks have also been intruded by at least three periods of pegmatite dykes with K-Ar ages of 2,000--2,100 Ma, 1,900 Ma and 1,700 Ma respectively (Yuqi *et al.*, 1973).

The intermediate unit Wutai Group, so far assigned to Lower Proterozoic, has recently been subdivided into three units by two unconformities within it. They are in ascending order Shizui, Taihuai and Gaofan Subgroups. The Shizui, with a thickness of about 3,000 m, and unconformably overlying the older Archean basement, starts with pebble-bearing quartzite, and is composed chiefly of mica-quartz schist, plagioclase amphibolite and biotite granulitite, intercalated with kyanite schist, hornblende schist, serpentinite, BIF and tremolite marble in the lower position, originated from turbidite-like terrestrial clastics, tholeiite, volcano-clastic, "semipelitic" and some pelitic types. The rocks were metamorphosed under amphibolite facies condition. The Taihuai Subgroup, up to 3,000 m thick, contains chlorite-schist, sericite-quartz schist, BIF, some quartzite lenses and basal metaconglomerate, mainly of greenschist facies. The rocks were derived from tholeiite, rhyodacite and its tuffs, and also some spilitic to keratophyric types. And the Gaofan Subgroup is about 800 m thick, comprising graded phyllite, metasiltstone, quartzite and some intercalations of graphite--bearing beds, of low grade greenschist facies. The protolithic rocks were of sandy and pelitic turbidites. Both the lower and middle Subgroups were invaded by granitic and tonalitic rocks, some accompanied by migmatization and granitization. U-Pb isochron method gives an age of 2,510--2,520 Ma[15] on zircon for the granite. Hence the formation age of both the lower and middle subgroups of Wutai is older than 2,520 Ma, but younger than 2,560 Ma (*vide supra*). Besides, two groups of whole rock Rb-Sr isochron ages[16] ranging from 2,300 to 2,400 Ma, and 1,700 to 1,800 Ma may represent two stages of metamorphism and related thermodynamic events for Wutai itself and Hutuo respectively.

The upper unit Hutuo Group with a great thickness of about 10,000 m, and provisionally regarded as also of Lower Proterozoic, comprises three subgroups, which exhibit as a whole rhythmic deposition of a grade scale with minor "cycles" composed of coarse clastic, sandy, pelitic to stromatolite-bearing Mg-rich carbonate types and also some basic volcanics. The rocks have mostly been metamorphosed to greenschist facies, only locally being migmatized. The age of 1,862 Ma[17] obtained by K-Ar analysis on hornblende, and Rb-Sr whole rock isochron analysis gave an age of 1,767-1,851 Ma[18]. All these indicate the probable metamorphic date.

THE NORTHERN SLOPE OF EASTERN QINLING RANGE AND ITS NEIGHBOURING REGION (VII, Fig. 1) Lower Precambrian formations of this district are found in a belt more than 500 km long, stretching from 109°E longitude to 114°E, within a N-S boundary between 33°N latitude and 35°30′ N, and thus including the northern slope of eastern Qinling Range in Shaanxi and the mountains along the eastward and east-southeastward extension in Henan. This may further extend to the buried metamorphics under the Quaternary in the district of Huoqiu, Anhui.

Archean metamorphics showing various degrees of migmatization have been denoted by different names such as Dengfeng Group, Taihua Group in different parts of this region, of which the Taihua Group, with a thickness about 9,000 m, and of widest distribution is well developed in Lushan, Henan Province and furnishes a type section composed chiefly of plagioclase gneisses containing biotite and/or hornblende and subordinately of granulitites and also some marble. The parent rocks of Taihua were mainly members of a volcano-sedimentary formation relatively

[14]Determinations made by Liu Dunyi of the Institute of Geology, Chinese Acad. Geol. Sc., which will be listed in a paper in preparation

[15]Determined by Liu Dunyi

[16]Determined by Zhong Fudao and Liu Dunyi, listed in a paper by Tao Quan submitted to "SEPCMV" Shenyang, 1981

[17]Age determinations made by the Yichang Institute of Geology and Mineral Resources, Chinese Acad. Geol. Sc., (Yuqi *et al.*, 1982)

[18]Determined by the Institute of Uranium Geology of Beijing and Zhong Fudao, listed in a paper by Tao Quan submitted to "SEPCMV" Shenyang, 1981

Table 1 – The correlation-table of Lower Precambrian, Northwestern China

Erathem	Tian Shan		Western Kunlun Shan	Altun Shan-Qilian Shan						
	Kuruktag	Kalpin-Muzhart He		Dunhuang	Shule Shan	Sunan-Qilian	Longshou Shan	Hualong	Lanzhou	Haiyuan
Changcheng System of Upper Precam.	Yangzibulak Group		Sangzutag Group	Baixiang Group	Danghe Group	Zhulongguan Group	Dunzigou Group		Xinglongshan Group	Haiyuan Group
Lower Proterozoic	Xingditag Group	Aksu Group	Ailiankat Group	Dunhuang Group	Yemanan-shan Group	Beidahe Group	Longshou-shan Group	Hualong Group	Maxian-shan Group	
Archean	Daklak bulak Group	Muzharthe Group	Karakax Group							

rich in iron, with the volcanics changing from basic composition to intermediate-acid and the "semipelitic" types increasing in amount from the lower part upward. Most of them are metamorphosed to an amphibolite facies, while those of the lower part may attain to granulite facies. Both the Linshan and Dengfeng Group are exposed to the north of the Taihua belt and of relatively limited distribution, characterized by the practical absence of marble. The U-Pb, K-Ar, Pb-Pb isochron and Rb-Sr isochron determinations[19] so far obtained have shown that both the Taihua and Dengfeng metamorphics exhibit three age groups, *i.e.* 2,600 ±, 2,200-2,300 and 1,800-2,000 Ma, probably representing three stages of metamorphism and related migmatization. The first indicates the isotopic date for metamorphic epoch towards the end of Archean, while the latter two may reflect the imprints of the two successive periods of metamorphism to which the Wutai and the Hutuo Group were subjected.

The lower Proterozoic Songshan Group with a thickness of about 2,000 m lies unconformably over the Dengfeng and under the Upper Precambrian. It comprises quartzite, mica(chlorite)-quartz schist, phyllite and some marble of the greenschist facies, derived from rhythmic sediments of coarse to fine clastics, pelites and also some carbonates. Its age of formation is older than 1,800 Ma as indicated by a Rb-Sr whole rock isochron corresponding to 1,799 Ma[20] and radioactive dating values.

[19]Made by the Yichang Institute of Geology and Mineral Resources, Chinese Acad. Geol. Sc., Institute of Geology, Academia Sinica and Institute of Uranium Geology of Beijing (Yuqi *et al.*, 1982)

[20]Determinations made by the Institute of Geology, Academia Sinica (Yuqi *et al.*, 1982)

The metamorphic formations of Zhongtiaoshan mountain in Shanxi, are also of Lower Precambrian age.

NORTHWESTERN CHINA (VIII, Fig. 1) Old metamorphic formations are scattered in many places in the northwest, but are chiefly found in the mountains of the western part of Kunlunshan, Tianshan, Altunshan, Qilianshan, etc. Their Early Precambrian age subdivision into Archean and Lower Proterozoic are based chiefly on geological reasoning and correlation and the unconformable contacts within the metamorphics as well as those with the overlying Upper Precambrian rocks. The names of the various Lower Precambrian formations in different districts and their correlation are given in Table 1.

There is a well defined succession developed in Kuruktag, Tianshan region. The Archean Daklakbulak Group consists mainly of garnet-biotite schist, biotite-quartz schist and amphibolite schist intercalated with some marbles, derived from "semipelitic" types and some carbonates, slightly or deeply migmatized. The Early Proterozoic Xingditag Group lies unconformably over the Daklakbulak Group and under the Upper Precambrian. It contains biotite- and amphibolite schists, marble and taconite, originated from pelitic, carbonate and intermediate to basic volcanic types. Both the two groups mentioned above were subjected to regional metamorphism of amphibolite facies, and invaded by the Early Precambrian granite.

In addition to the Lower Precambrian of the eight regions just mentioned, there are two small areas, one in southwestern Sicuan Province (Hekou Formation of Huili Group) and another in central Yunnan (Dahongshan Group), where low to median grade metamorphics possibly also of Early Proterozoic age, have been found.

Table 2 – The correlation chart of Lower Precambrian of China

Erathem	I Liaoning and Jilin	II Eastern Shandong	III Central and Western Shandong	IV Huaiyang	V Yanshan	V Yinshan	VI Wutai-Taihang-Luliang	VII Northern slope of E. Qinling	VIII Northwestern China
Lower Proterozoic	Liaohe Group	Fenzishan Group		Hong-an Group	Qinglonghe Group	Majiadian Group	Hutuo Group	Songshan Group	Xingditag Group
2,500-2,600 Ma	Kuandian Group						Wutai Movement		
					Shuangshanzi Group	Sanheming Group	Wutai Group		
							Tiepu Movement		
		Jiaodong Group	Taishan Group		Badaohe Group	Wulashan Group (M)	Longquanguan Group		
Archean ca. 3,000 Ma	? Anshan Group (M)			? Dabie Group			Fuping Group (M)	Dengfeng Group	Taihua Group (M) / Daklakbulak Group
					Qianxi Group (M)	Jining Group (M)			

(M): With strata belonging to granulite facies

CORRELATION OF THE LOWER PRECAMBRIAN FORMATIONS Based on the above description, a tentative scheme of correlation of the major Lower Precambrian stratigraphic units of China is given in Table 2. In most of the regions, these old metamorphics are divided into a lower stratigraphic unit of Archean age and an upper one belonging to Early Proterozoic usually separated by an unconformity, which was formed during the Tiepu Movement[21] roughly corresponding to the Kenoran Orogeny of Canada (Stockwell, 1982) and its equivalents elsewhere in the world. The chronological demarcation has been taken as 2,500-2,600 Ma which roughly corresponds to that of the end of a late Archean metamorphic period. Both units are further divided into two groups in part of the regions listed. In some districts the Archean metamorphics also show isotopic ages around or older than 3,000 Ma, which may indicate the presence of an early period of metamorphism.

[21] An orogenic movement which gave rise to the unconformity between the Fuping Group and the Wutai Group. This has also been named as Fuping Movement (Xingyuan *et al.*, 1981)

SUMMARIZING REMARKS: CERTAIN EVOLUTIONAL CHARACTERISTICS OF THE LOWER PRECAMBRIAN OF CHINA Archean rocks are found chiefly in the broad North China Platform and composed mainly of biotite or amphibole-plagioclase gneisses, biotite granulitite and plagioclase amphibolite of the amphibolite facies, with the lower part containing biotite-pyroxene-plagioclase gneiss and pyroxene granulite of the granulite facies and cropped out mainly on the northern margin of the platform.

The parent rocks were not well differentiated sedimentaries, volcano-sedimentaries and volcanics of basic to intermediate-acid composition, forming two major volcano-sedimentary cycles which were well developed in part of the Yanshan region. There the lower one, represented by the Qianxi Group, exhibits an upward gradation from basic volcanics to intermediate-acid lavas and related pyroclastics, and the upper Badaohe Group shows an upward transition from basic volcanics to intermediate-acid tuffaceous sedimentaries. With the exception of the Yinshan region (Jining Group), so far only formations of the second cycle have been found in all the other regions.

The principal rock types of the Archean terrains mentioned above, show obvious similarities in their petrological features, particularly in the mean value of chemical composition (Dazhong *et al.*, 1982).

There is no well marked linear metamorphic zonation and the rocks of the same periods distributed within certain extension in different areas have usually undergone metamorphism of about the same grade. Wherever more than one metamorphic facies exists, then the boundary of the stratigraphical units is concordant with that of the metamorphic grades.

The Archean strata were extensively folded. It is well seen that the superposition of at least two late major fold systems of the different tectonic stages and orientations of Archean has been recognized. And the boundaries of metamorphic facies as well as those of strata had been involved in the disturbance.

All the striking features indicated above show that, during the Archean time, the geological environment over an extensive area was quite uniform yet tectonically fairly active and no rigid tectonic boundaries have been found to occur in the terrain.

In the Archean along the borders of the North China platform there are normal sedimentary carbonate rocks with intercalated arkosic sandstone and others, while in its central part, including the regions of eastern Liaoning and southeastern Jilin, southern flank of Yanshan mountain, central and western Shandong, central north Henan (Dengfeng Group) and probably also the buried metamorphic basement beneath the Hebei Plain, such sedimentaries are rather rare. This reflected the mobile nature of the central part and the conditions of sedimentary differentiation of the border zone for a certain span of time. Towards the end of Archean around 2,500 Ma prolonged period of median- to high-grade metamorphism often accompanied by rather intensive migmatization came to an end.

In the Early Proterozoic time, a thick sequence of volcano-sedimentaries were accumulated in some marine troughs regarded as eugeosynclinal (Xingyuan *et al.*, 1981) and developed on the Archean sialic basement such as those found in the Wutaishan region – the Wutai Group. The original rocks were characterized by the rather widespread occurence of partially sodic volcanics and the abundance of "semipelitic" and pelitic types and turbidites, with the frequent association of coarser terrestrial clastics in the lower part. They were intruded by granitic and tonalitic bodies not later than 2,500 Ma in certain regions and subjected to regional metamorphism, mainly of greenschist facies and partly up to amphibolite facies and sometimes accompanied by migmatization probably not later than 2,300 Ma during the Wutai Orogeny[22]. Such types of metamorphic formations were formed in three belts, *i.e.*, the first one now extends from Jilin and Liaoning westward, through Yanshan and Yinshan to Tianshan in the north, the second appears in the Huaiyang region, northern slope of eastern Qinling, Qilianshan, Altunshan, western Kunlunshan, etc., in the south, and the third one in the Wutaishan-Taihangshan-Luliangshan region.

The extent of the sea became smaller after the Wutai Movement than before. The stratigraphic pile accumulated in the marine basins or troughs often regarded as miogeosynclinal in character, as represented by the Hutuo Group of Wutaishan, was composed of clastic, pelitic and stromatolite-bearing Mg-rich carbonate sedimentaries which show rhythmic deposition on a wide scale and also numerous minor ones, with local contemporaneous lavas of basic composition. The degree of sedimentary differentiation thus exhibited and together with the two internal unconformities within the Hutuo reflected the frequent fluctuation of the environment of sedimentation and the unstable nature of the crust during deposition. The metamorphism of greenschist facies suffered by the Hutuo Group rocks probably occurred during 1,740-1,900 Ma and this marked the end of the Early Precambrian history.

P. S. Owing to the complicated constitution of the Lower Precambrian and its later changes, the difference in the extent to which the areal geology of the ancient metamorphic terrain that has been studied, the presence of certain intricate problems concerning the geochronological research still remaining unsolved, and the fact that the investigations of the stromatolites and micro-palaeobotanical remains of certain Early Precambrian formations are still in their early stages, indicate that there are quite a number of problems regarding the age, subdivision and correlation of certain Precambrian stratigraphic units not yet solved. For example, opinions still differ regarding the exact stratigraphic position of the lower part of the Archean sequence, the Wutai Group of Shanxi, and also certain upper stratigraphic units already assigned to Lower Precambrian such as the Hutuo Group and the exact lower time limit for the Upper Precambrian.

Besides, although some reports concerning greenstone belt were carried out on the ancient metamorphic assemblages in some regions, such as eastern Liaoning, central Shandong, northern slope of Qinling Range and Wutaishan region, it is still a difficult problem to discriminate between the high grade region and greenstone belt of Early Precambrian terrain in China.

It seems that this does not depend simply upon the degree of metamorphism, and in fact involves integrating investigations of the geological environment for the formation of protolithic rocks, the tectonic evolution they had undergone as well as their compositional and petrological characteristics. It is even more difficult to answer the question whether there existed any trace of plate tectonics in the Early Precambrian.

[22]A movement which gave rise to hiatus between the Wutai Group and the Hutuo Group

REFERENCES

DAZHONG, S. and CHANGHUA, W. – 1982 – Principal geological characteristics of the Archaean in North China. *In*: Archaean Geology: Second International Symposium, Perth, 1980. Special Publication N.° 7 of the Geol. Soc. of Australia (in press).

STOCKWELL, C.H. – 1982 – Proposals for the time classification and correlation of Precambrian rocks and events in Canada and adjacent areas of the Canadian Shield, Part 1: A time classification of Precambrian rocks and events. *Geol. Survey of Canada*, Paper 80-19, 135 pp.

XINGYUAN, M. and ZHENGWEN, W. – 1981 – Early tectonic evolution of China. *Precambrian Research*, **14** (1981): 185-202.

YUQI, C., FUDAO, Z. and YONGJUN, S. (Yuchi, C., Futao, C., and Yuntsun, S.) – 1973 – The Pre-Sinian of Northern and Northeastern China (in Chinese). *Acta Geologica Sinica*, 1 (English text printed in Beijing in 1972).

YUQI, C., JIN, B. and DAZHONG, S. – 1982 – The Lower and Middle Precambrian of China. *In*: An Outline of the Stratigraphy in China (in Chinese with English summary, in press), Beijing, Geol. Publishing House.

YUWEI, C. *et al.* – 1981 – Pb isotopic age determinations of some Precambrian rocks from North China – Additional discussion on Precambrian geochronological scale of China (in Chinese with English abstract). *Geochimica*, 3 (1981): 209-219.

Recebido em 31 de julho de 1982