中国前寒武纪矿床和构造

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中国工作组

张贻侠　刘连登　主编

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IGCP PROJECT 247
OF THE WORKING GROUP OF CHINA

Editors in Chief
Zhang Yixia Liu Liandeng

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内 容 提 要

将矿床作为构造的指示物，或者说通过前寒武纪构造演化来分析矿床的形成与成因，是本书的重要特色。书中对我国韧性剪切带与金矿的有关问题，首次作了系统的论述；全面、深入地总结了太古宙绿岩带和元古宙构造环境中的矿床类型。全书反映了我国的寒武纪矿床和构造研究的最新成果和先进水平，并同国外进行了有益对比。

本书是国际地质对比计划第 247 号项目中国工作组提交给国际工作组和地科联的总结报告。本专著实际资料丰富、学术思想新颖，具有较高的学术价值。可供从事前寒武纪地质和矿床研究的科技人员、高校地质类的本科生和研究生参考。

中国前寒武纪矿床和构造

张贻侠　刘连登　主编
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序

自 1986 年开始的国际地质对比计划(IGCP)247 号项目，经过各国同仁的努力，于 1992 年底顺利地结束了。作为这个项目的总结，1991 年底中国工作组等单位受项目工作组的委托出版了《国际前寒武纪矿床、构造及地球物理学术讨论会论文摘要集》。该文集汇集了包括太古宙成矿作用与构造，早元古宙成矿作用与区域构造，前寒武纪大型与超大型矿床模型，活化地盾(陆台)区的成矿作用，前寒武纪韧性剪切带与矿床关系，地球物理方法在前寒武纪矿床、构造研究中的应用，地球物理方法在区域和深部地质研究中的应用以及其他共八个部分、75 篇论文的中、英文详细摘要，总计 48 万字，由原苏联、芬兰、印度、澳大利亚和中国的同仁撰写。文集除赠送给有关人士外，已由项目负责人之一 V.I.Kazansky 教授转呈给 IGCP 委员会。

IGCP 247 项目的研究，几乎涉及到与前寒武纪矿床相关的所有重要领域。其中成矿作用与构造演化的关系，特别受到项目参加者的关注。如果把矿床作为构造的指示物来研究，或者通过构造演化来分析矿床的形成，都会引出相得益彰的成果。这一概念，不仅对于研究前寒武纪矿床的地质学家是重要的，而且对于所有的矿床学家和构造学家都是有益的。在去年京都召开的 29 届国际地质大会上，这一趋势反映得十分明显。

我们高兴地看到，中国地质学家在这一领域做出了可喜的贡献。如果不把他们的成果公诸于世，将是一件憾事。这就是为什么我们在出版了上述论文摘要集之后，还要出版这本论文集的原因所在。

这本题为《中国前寒武纪矿床和构造》的中文文集，只选辑了 10 篇文章。尽管远非本项目所涉及的全部研究成果，但毕竟有相当的代表性。俗话说"抛砖引玉"。如果这本文集能够促进我国前寒武纪矿床与构造研究更上一个新的台阶，这将是对作者们的一个莫大的鼓舞。读者会看到书中矿床的成因观可能存在着某些差异，显然这是一个好现象。作为一本文集，充分体现百家争鸣的精神，会利于学术的繁荣。

世事往往是"好事多磨"的。本来拟定在 1991 年 10 月于长春召开的 IGCP 247 项的结题国际学术会议，临时因故而未果，是一憾。由于种种原因，此文集出版晚了一段时间，但毕竟还是一一完成了。以补所憾，于心稍安。

这里，我们要向 IGCP 247 号项目的负责人 V.I.Kazansky 教授、G.Goal 教授和 S.C.Sarker 教授致意。正是由于他们的不懈努力，本项目才能得以顺利开展。我们还要向已故的 张秋生 教授表示深切的怀念，这是他所倡导和曾主持的第二个国际对比项目。不幸的是他意外早逝，死非其时。我们只有努力完成他的宿愿，以慰他在天之灵。

张贻侠、刘连登

IGCP 247 项中国工作组

1993 年 10 月 30 日

于长春地质学院

PREFACE

The project 247 of International Geological Correlation Programme (IGCP) began in 1986, was smoothly finished by colleagues all of the world who worked in common efforts at the end of 1992. As the project summary, the chinese working group entrusted by the project working group published 《Theses Abstracts of Symposium on International Precambrian Ore Deposits、Tectonics and Geophysics》 at the end of 1991. The collected works consists of eight parts. They are: Archaean Metallogeny Related to Tectonic Styles; Early Proterozoic Metallogeny and Tectonics; Geological Models of Precambrian Large Ore Deposits; Metallogeny in Active Cratons; Relationships between Precambrian Ductile Shear Zones and Ore Deposits; Application of Geophysics to Researches of Precambrian Ore Deposits and Tectonics; Application of Geophysical Methods to Researches of Regional Geology and Deep Crustal Tectonics; etc. The collected works includes 75 detail abstracts in chinese and English, and 300 pages, written by colleagues from pre–USSR、Finland、India、Australia and China, besides being gifted experts related, The collected works was presented to IGCP committee by prof. V.I.Kazansky who is one of the leaders.

The study of IGCP project 247 almost touches upon all the important fields related with precambrian ore–deposits, The relationship between metallogeny and tectonic evolution of which especially is concerned by the project participators. It will leads to outcomes that one improves by association with the other for geologists to study ore deposits as indicators of tectonics and to analyse ore deposits forming by tectonic evolution. The concept is not only important for geologists to study precambrian ore deposits but also useful for all the economic geologists and tectonic–geologists. The trend occurred evidently in the 29th International Geological Congress hold in Kyoto ,Japan, 1992.

We are pleased to find that Chinese geologists have contributed a lot to this field. It will be a matter for regret that their outcomes can not be made known to the world, which just is why this collected works 《Precambrian ore deposits and tectonics in China》 must be published publicly after publishing the theses abstracts mentioned above.

Only are ten articles chosen in the collected works, they are far from the all research outcomes involving in the project 247, but have quite representation.

Old saying says "throw stones and bring back jade". The collected works can make research on chinese precambrian ore deposits and tectonics strive for further improvement, authors will gain great inspiration. Readers will find there are some different in the viewpoint of metallogensis in the collected works, that is not bad evidently, because difference in the viewpoint of metallogenesis can spur a hundred shools of thought contend, benefit academia prosperity.

"Accomplishment of anything good entails many twists and turns." originally, we made up convoking international symposium of IGCP project in Chang Chun in Oct. 1991. It was a matter for regret that we did not realize our wish for some reasons at the last moment. Maybe ,we will feel comfortable to finish everything to compensate our matter for regret.

Here, give our best wishes to prof. I.V.Kazansky, prof.G.Goal and prof. S.C.Sarker. Who are responsible for the IGCP project 247. The project can be carried out smoothly just as a result of their untiring efforts. We deeply cherish the memory of prof. Zhang Qiusheng who passed away unluckly too early. The project 247 is the second international correlation project that prof. Zhang Qiusheng initiated and took charge of. Let's make great efforts fulfil his long-cherished wish to console his soul in the heaven.

Zhang Yixia Liu Liandeng
IGCP project 247
Chinese working group
Oct. 30. 1993
Chang Chun.

ARCHAEAN GREENSTONE BELTS AND RELATED ORE DEPOSITS IN THE NORTH CHINA PLATFORM

Shen Baofeng Peng Xiaoliang Luo Hui Jin Wenshan
HuXiaodie Li Shuangbao Li Junjian Chen Yonghua

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Abstract

Archaean cratons constisting of the high-grade terrains and granitoid-greenstone belts are widespread in the North China Platform. The greenstone belts are mainly exposed in the regions of Helong and Giapigou, in Jilin Province, Qinyuan and Anshan-Benxi, in Liaoning Province, Xiaoqinling in Henan and Shanxi Province, Guyang, in the inner Mongolia Autonomous region, Qinlong-Lanxian, in eastern Hebei Province, Wutai Mountain, Denfeng and Loushan-Wuyang, in Henan Province, Dabian Mountain and Eastern Shandong Province, etc, especially concentrate in the northern and southern margins of the North China Platform. The irregular banded greenstone belts destribute in the granitoid and "TTG" gneisses, consist predominately of mafic volcanic rocks double-layered ultramafite, and esitic-felsic volcanic rocks and sedimentary rocks that have been metamorphosed to high greenschist facies-low amphibolite facies grade and deformed intensely. It forms in late Archaean (Ca.2.5-2.9 Ga). The tectonic settings of the greenstone belts are similar to the rift of the marginal sea basin, island-arc and the continental marginal rift.

According to the occurrence and forming times, the granitoid associated with the greenstone belts can be divided into three series: tonalite-trondhjemite-granodiorite series (TTG series), kaligranite series and metasomatic remelting granits series. The TTG series being bound up with the greenstone belts belong to Late Archaean intrusive rocks. Most of them are of the occurrence of batholith, stock or chonolith. The banded and elliptiform kaligranite series distribute along the shear zone emplace in the cooling greenstone belts in the priod of Late Archaean or Early Proterozoic Era · the metasomatic remelting granite series are produced by the partial melting of the greenstone belts in Mesozoic Era. The geochemical characteristics are different among the three series.

The Archaean greenstone belts are main gold-bearing rock series. Most of the gold deposits occur in the granitoid-greenstone belts. On the basis of ore material resources, geological setting of mineralization and host rock, the gold deposits are classified into the primary and regenerated deposits, which can be subdivided into five categories: I)

stratabound gold deposits, Ⅱ) gold deposits in veins and shear zone, Ⅲ) sandstone–conglomerate gold deposits, Ⅳ) metasomatic remelting magmatic hydrothermal gold deposits, Ⅴ) gold deposits relating to the Andesitic–felsic volcanic–intrusive rocks. The categories of Ⅱ) and Ⅳ) are important in the total. The different gold deposits are formed in the different stages of the formation and evolution of the granitoid–greenstone terrains. Therefore, the geological characteristics of every type are different and related.

The iron deposits occurring in the Archaean greenstone belts are the most important type of iron ore in China. The iron orebodies are beded, bed–like and lenticular, contact conformably with the country rocks. In terms of the geological tectonic setting and the rock assemblages, the iron deposits are similar to the Algoma–type and can divide into three types:amphibolite–magnetite quartzite, amphibolite (or chlorite–schist)–biotite leptynite–magnetite quartzite and biotite leptynite–magnetite quartzite, in which the later two types are improtant. It is suggested that the well–differentiation of magma, a large scale eruption and the low frequency of cycle of volcano provide a stable sedimentary ervironment and material of mantle–source that benefit the formation of the large scale iron deposits.

The massive sulfide deposit in the Archaean greenstone belts distributes in the Northern Liaoning Province. It is the oldest Zn–Cu massive sulfide deposit at present in China. The occurrences of the ores are strictly bounded to the assemblage of the interbedded leptynite, leptite and schist im middle to upper parts of Hongtoushan formation, Qinyuan group. The deposits have undergone multistages of metamorphism and deformation. Some of the ores are formed by the reemplacement.

The basic characteristics of the greenstone belts of the North China Platform, Abitibi, Yilgarn, Zimbabwe and Barberton are similar, but exist differences evidently. The differences between the North China Platform and others reflect the specialities of the formation and evolution of the crust of the North China platform.

RELATIONSHIPS BETWEEN GOLD DEPOSITS AND DUCTILE SHEAR ZONES AND OVERPRINT STRUCTURES

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Abstract

China is one of the most improtant gold producers in the world, following Africa, Pre–USSR and USA. Almost 70%of the proved gold reserve comes from North China Platform. The characteristics of gold deposits in the Platform deffer from that in other countries, more ancient hosted rocks (Archean or early proterozoic) and younger mineralizing age for the major gold deposts.

Tectonogneiss and ductile shear zones are commonly found in the early Precambrian metamorphic regions. Tectonogneiss is the results of plastic flow during the processes of metamorphic crystalization and deformation. Ductile shear zones occur spacially in bands and are occupied by mylonite. Ductile shear zones develop spacially on the background of the tectonogneiss in North China Platform.

On basis of the spacial, temporal and genetic relationships between gold deposits and ductile shear zones, three descriptive types of the gold deposits can be classified: DUCTILE SHEARING GOLD DEPOSITS. SYN–AND POST–DUCTILE SHEARING GOLD DEPOSITS. Ductile shearing gold deposits are referred to that gold concentrated from Au–rich sulphide ore bodies by the ductile shearing occurred during regional metamorphism. Those epigenetic gold deposits, which formed during the late stage of the ductile shearing process and controlled by ductile shear zones spacially and temporally, are called syn–ductile–shearing gold deposits. Some gold deposits, are formed in different stages and geological environments contrary to ductile shear zones, called post–ductile–shearing gold deposits. They are controlled by long–life overprint structures spacially, especially by the brittle fault systems overimposed on the ductile shear zones. The geneses and the mineralization processes of the late two types of gold deposits must be studied carefully.

The most important industrial type of gold deposits found in the North China Platform is post–ductile–shearing gold deposits. Maybe it originated from remelting magmatic

fluids in Mesozoic (especially in J–K). Gold lodes occur usually during the intrusion of varied dikes and come from the same source as the granitic rocks, which are formed by the remelting of the Archean metamorphic rocks. The summary of the global gold deposits without including this type is incomplete.

THE GEOLOGICAL SETTINGS OF XIAOQINLING GOLD DEPOSITS, WESTERN HENAN, CHINA

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Abstract

Xiaoqinling gold deposits occur in the Archaean granitoid–greenstone belts of the southwestern margin of the North China platform, consist of more than a thousand gold–bearing quartz veins in the mineralization field of 900km^2.

The granitoid–greenstone belt is a narrow belted paleo–uplift trending EW that consists of trondhjemitic, tonalitic and granodioritic (TTG) gneisses and irregular and beded greenstone belt. The strata of the greenstone belt is the Late Archaean Taihua group that can be divided into two parts, a lower subgroup include Lujiayu formation and upper subgroup include Guanyintang and Huanchiyu formations. The Lujiayu formation mainly consists of amphibolite, the Guanyintang formation is composed of quartzite, magnetite quartzite, amphibolite, biotite–leptynite and a little of marbles and the Huanchiyu formation consists of metamorphosed carbonate rocks dominantly and a little of amphibolite, biotite–lepcynite and garnet–sillimanite leptite. The original formation is composed of mafic–felsic volcanic rocks, pyroclastics and sedimentary rocks, which have been metamorphosed by amphibolite facies. The area of the Archaean "TTG" gneisses is more than 80% in total. The gneisses are Archaean composite intrusive bodies formed by multistage intrusion. The chemical compositions of the gneisses are summarized as following: the content of SiO_2 between varies 58.79–74.2%; Al_2O_3, 11.9–19.66%; Na_2O / K_2O, 1.2–2.6; and the oxide of Ti, Ca, Mg, and Fe decreased directly as the SiO_2 increased. The gneisses belong to the Calc–alkaline series in AFM diagram. The REE patterns show a sharp slope, LREE enrichment is positive and on anomaly of Eu ($Eu / Eu^* = 0.95–1.6$). The "TTG" gneisses and the dark amphibolites make up a bimodel distribution in the histogram of SiO_2, there are not the 55— 65% content of SiO_2. The diagram of $K_2O–SiO_2$ shows that the TTG series are formed in continental environment, the primary rate of $^{87}Sr / ^{86}Sr$ of the TTG series is 0.703, similar to the amphibolites (0.701), and show that sources of TTG series are from the mantle.

The gold veins are widespread in the granitoid–greenstone belts, predominantly occur

in the "TTG" gneisses associated with the amphibolite of the lower subgroup, occur in the anticlinal axis spatially. Most of the veins occur singlely, swell, offset and compounding locally. The kinds of the ore are pyrite–quartz vein and polymetallic sulfides–quartz vein. The ore minerals are mainly pyrite, chalcopyrite, ganlenite, sphalerite, native gold and electrum. Quartz is the main gangue mineral and others are carbonate minerals. The distribution of the bearing–gold quartz vein is contralled by the ductile shear zone trended from east to west. The ductile–brittle shear zone is developed in the Archaean "TTG" gneisses and some of amphibolite and characterized by the intense schistositized–mylonitized zone. The gold mineralization has been found in the brittle fault zone evolved from the ductile. The largest shear zone in which the lode of Yangziyu No.60 occur is 7.7km long. The trended direction of the shear zone accords with that of the regional structural line. The stress field forming the shear zone derives from the SN directional pressure. The mylonites consist of protomylonite, mylonite and ultramylonite. The main associated mineral assemblage is composed of seritite, quartz, feldspar, chlorite and carbornate etc., which represents the metamorphism of the typical greenschist facies and differs from the regional metamorphism of amphibolite facies. It shows that there is the regressive metamorphism in the shear zone. The mylonites have been altered. The main alteration includes sericitization, carbonatization, biotitization, potash–feldsparitization, silicification and chloritization. The contents of CO_2 and H_2O increase gradually with altering intensely. The contents of the FeO^*, CaO, MgO, TiO_2 and the ratio of Na_2O / K_2O increase with the decrease of the SiO_2 and Al_2O_3. The studies of the compositions of the fluid inclusions of quartz in the ores show that the ore–forming hydrothermal is the mid–weak acid solution belonging to the type of Na–Ca–Cl–(HCO_3)–H_2O, the peak ore–forming temperature is 200–300℃ and the pressure is 0.108–0.163GPa. On the basis of the δD and $\delta^{18}O$, the solution is similar to metamorphic water added meteoric water in later period. The similarity of the stable isotopic constitution ($\delta^{34}S$, $\delta^{18}O$, $\delta^{13}C$ and Pb–isotope) between the ore and the host rock implies that the ore–forming material and the hydrothermal solution are derived from the greenstone belts. The Pb–isotopic constitution in feldspar and ores accords with an evolutional model of two stages. It is obvious that the first enrichment of the gold occured in 1.8 b.y.age and the second in Mesozoic Era.

JIAPIGOU GOLD DEPOSIT AND ITS RELATED DUCTILE SHEAR ZONE

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Abstract

The jiapigou gold–deposit is a gold ore zone consisting of more than 10 large, medium and small–scale quartz vein–type gold deposits as well as hundreds of mineralized points .It is located in one side of greenstone belt between the Jiapigou Archaean granite–greenstone belt and potash feldspathization zone in high–grade terrains. The orebodies are occurred in ductile shear zone. Gold ore zones have closely spacial and genetic relationship with ductile shear zone, greenstone belt and potash feldspathzation zone.

The ductile shear zones controlling ore are referred to both northwest and northeast shear zones in this area. They are derived from the second stage of structure deformation, an important structural event in Early Proterzoic. The Jiapigou late Archaean granite–greenstone terrain is seperated from Longgang middle Archaean high–grade terrain by northwest ductile zone, that may be the result of hereditary mobility of deep fracture controlling the Jiapigou greenstone belt. It is the main structure influencing the formation and evolution of greenstone, by which formed the gold deposits.

The main marks of ductile shear zone are characterized by a series of mylonites, various ductile folds, close foliation, widespread retrogressive metamorphism and frequent magmatic intrusion. The mylonite may be divided into four types: mylonitized rock, protomylonite, mylonite and ultramylonite. Many features of ductile deformation can be found in mylonite, shch as mylonite foliations, stretching lineations, quartz deformation bands and lamellaes, subgrains, dynamic recrystallizations, flexural feldspar twins and so on. Obvious rotational strain in mylonite is reflected by asymmetric augen structures, micafishes, pressure shadows, S–C structure, and preferred orientation of c–axis. The microstructural features of ductile deformation show that the direction of movement of ductile shear zones is perpendicular to the strike of ductile shear zone. The ductile deformation can be divided into three stages: low–temperature and high–strain (quench), high–temperature and low–strain (recovery), high–temperature and high–strain (recrystallization) stages. According to the measuring quartz strain axis and calculating value, the deformation mechanism of shear zone is dominantly simple shear and concurrently flattening. Late–brittle faults frequently superposed on early high–ductile strain areas.

Au-mineralization and Au-deposit are confined within shear zones, without any exception. The orebodies appeared as groups and concentrated in some areas, and controlled by northwest and northeast shear zones. The spaces producting Au-deposit are closely concentrated in the areas of ductile shear zones. The gold-bearing quartz veins are mostly located in the centre of strong strain, especially, those of high-grade and wide vein exist in mylonite and ultramylonite; hardly distributed in week strain areas, for example, in mylonitized rock and protomylonite. The dip angles of orebodies are mainly of high-dipping and some of them near-vertial. The attitudes of orebody are identical with mylonitic foliation's, whether the oredody occurs in either northwest or northeast shear zone. But they intersect the wall-rock schistosity in around 20° dip. The change of shape of shear zone controlled that of orebody. Wall-rock alteration superposed on mylonite zones, so that the wall-rocks of near orebodies were intensely altered. With K, CO_2, H_2O, and Au increasing largely, Fe, Mg, Ti, Al and Si mobilizing and migrating, the intense alteration produced chloritization, sericitization, carbonatization, cilicification and pyritization. The alteration have not obvious horizontal and vertical zonality.

The result of transmission electron microscopy shows that there are two phases of superposed quartz dislocation structures in gold-bearing veins, their strain features are different from each other. One phase show slow-temperature and high-shear strain, the other is middle-temperature and middle-shear strain. It means that gold-bearing quartz veins have undergone obvious ductile deformation and have not undergone high-temperature and low-shear strain (recovery) as well as high-temperature and high-shear strain (recrystallization). The gold-bearing quartz veins took emplacement, after strong deformation stage of ductile shearing. Because of crustal swellings, the shear zone was uplifted from lower-sublayer of infrastructure (> 15km) to upper-sublayer of infrastructure (5-10km). The defomation characteristics display para-ductile and the deformation types transformed from ductile into brittle-ductile or ductile-brittle.

The auriferous pyrite and polymetallic sulfide ores are the dominant gold ores. Native gold as a main auriferous mineral mostly occurs in pyrites and quartz fissure. It is often associated with galena and chalcopyrite, which formed in the stage of polymetallic sulfide. The fineness of native gold is high, averaging in 919. The change of Au / Ag ration, in general, does't show obvious regularity, but in some localities it increase with depth.