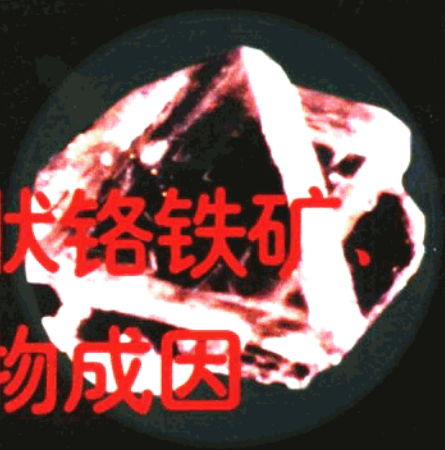


西藏罗布莎豆荚状铬铁矿、 金刚石及伴生矿物成因



白文吉 周美付 P.T.Robinson 方青松
张仲明 颜秉刚 胡旭峰 杨经绥 编著



地震出版社

西藏罗布莎豆荚状铬铁矿、金 刚石及伴生矿物成因

白文吉 周美付 P. T. Robinson 方青松 编著
张仲明 颜秉刚 胡旭峰 杨经绥

地 震 出 版 社

2 0 0 0

内 容 简 介

在蛇绿岩尤其是在豆荚状铬矿石中发现金刚石,引起了许多地质学家的兴趣。在西藏罗布莎豆荚状铬铁矿矿石中,除发现有金刚石外,还发现了与金刚石等共存的如石墨、自然硅、自然镍、自然铬、自然金等自然元素矿物和 FeNi, CrC, SiFe, LaAl 等合金矿物。此外尚有硅酸盐矿物、硫化物和氧化物等。本书揭示了古大洋地幔矿物的许多新信息,并以新颖的学术观点对豆荚状铬铁矿深部地幔成因进行了探索,展示了地幔超高压矿物和地幔环境新的研究方向。本书可做地幔物质成分研究的重要参考资料。

西藏罗布莎豆荚状铬铁矿、金刚石及伴生矿物成因

白文吉 周美付 P. T. Robinson 方青松 编著
张仲明 颜秉刚 胡旭峰 杨经绥

责任编辑:陈晏群

责任校对:庞娅萍

*

地质出版社出版发行

北京海淀民族学院南路9号

北京地大彩印厂印刷

全国各地新华书店经售

*

787×1092 1/16 6.5印张 7插页 200千字

2000年5月第一版 2000年5月第一次印刷

印数 001—200

ISBN 7-5028-1734-4/P·1035

(2232) 定价:30.00元

前 言

“西藏铬铁矿成因矿物学及找矿线索”研究项目基金，一部分来自中国国土资源部区域地质调查局，另一部分系由加拿大自然科学和工程学基金会 (NSERC) 资助。该项目于 1996 年秋立项，研究时间 3 年。于 1996 和 1997 年开始野外调查。参加调查的有：白文吉研究员、P. T. Robinson 教授、方青松研究员、周美付博士 (Department of Earth Sciences, University of Hong Kong)、Gareth Davies 博士 (Laboratorium Isotopen-geologisch Onderzoek, Vrije University Amsterdam, Netherlands)、Hubert Staudigel 教授 (同上)、Melanie Griseln 博士 (同上)、和胡旭峰硕士等。

铬铁矿中伴生矿物的初步选矿工作是由国土资源部郑州矿产综合利用研究所完成的。参加选矿试验的人员有李洪潮、张鸿源、张银年、张友珍、田敏、方青松和张仲明等。单矿物镜下挑选工作由白文吉、方青松、张仲明、颜秉刚、胡旭峰和 P. T. Robinson 完成。

该项目的主要任务和目标是对具有工业意义的西藏罗布莎铬铁矿及其中的金刚石成因、找矿标志和找矿线索进行探讨。罗布莎铬铁矿以其规模和富铬特点早就受到西藏自治区人民政府及我国地学界的重视。此外，还因它产于雅鲁藏布江缝合带内，而备受国内外地质构造学家的关注。70 年代末，地质矿产部地质研究所、成都地质研究所和地质力学所与西藏地质局合作，组成了西藏铬铁矿综合研究队。在 1979 年完成了该区铬铁矿综合研究任务后，地质矿产部地质研究所和西藏地质局合作于 1981 年又在西藏罗布莎和东巧两个蛇绿岩块的铬铁矿体和地幔橄辉岩中首次发现金刚石 (方青松、白文吉, 1981)。这一发现，引起了地学界的强烈反响，国内外地质学家、构造学家也十分重视。它不但提供包括铬铁矿和金刚石等地球深部矿物成因的重要信息，而且它对探讨地球深部环境及地质构造具有十分重要的意义 (Bai et al., 1993)。

西藏蛇绿岩铬铁矿中的金刚石，在其包裹体和矿物组合方面，都与金伯利岩和钾镁煌斑岩中的有所不同，英国金刚石专家 P. H. Nixon 教授在东巧的一颗金刚石的包裹体中发现了铁和镍，并联系到人造金刚石中有铁镍添加物，从而认为西藏金刚石可能是污染的 (与白文吉个人通讯)。还有少数金刚石研究者，如美国 Haggerty Stephen (1996) 认为在西藏发现的金刚石是人工合成的，并在 30 届国际地质大会上公开宣布。我们认为，Haggerty Stephen 的结论未免有失偏颇。众所周知，自然界中的事物千变万化，地质领域中出现的现象也不例外。正确的结论来源于对事物、特别是新事物的客观的、实事求是的科学分析，而不是用现成

的旧框框进行主观的臆断。

诚然, Chichester 钻石公司考察团 J. B. Howthorne 先生等人 1991 年 8 月在罗布莎和东巧两地也取过若干样品进行分选, 可能是由于取样过小(数公斤至 50kg)或是由于选矿技术问题, 未找到金刚石, 但这并不能作为否定西藏蛇绿岩橄榄岩和铬铁矿中存在金刚石的依据。

加拿大达霍希大学海洋地质中心主任 P. T. Robinson 教授, 对西藏蛇绿岩和铬铁矿的金刚石尤感兴趣, 并认为对其进行深入研究十分必要。为了对西藏金刚石和大洋板块俯冲作用等有关问题进行研究, P. T. Robinson 教授与中国地质科学院白文吉研究员会同国外的几位地质学家, 如 John Malpas 等, 向 NSERC 提出了财政申请, 并得到了基金资助。与此同时, 白文吉等也得到了中国国土资源部区域地质调查局基金的资助。通过阶段性研究, 该项目取得了突破性进展, 其中不但在铬铁矿中再次选到了金刚石, 而且还查明了一个由多种罕见矿物组成的矿物组合, 包括硅酸盐、氧化物、硫砷化物、自然金属和金属互化物等新矿物, 共 70~80 种。这些矿物可能反映了地幔深部 400~670km 内和地幔较浅部位的物理化学环境, 因此这一发现对研究深部地质尤其下地幔具有十分重要的意义。

本报告所取得的任何成绩都与国土资源部地质调查局的支持分不开, 陈毓川院士、张宏涛局长、朱明玉处长对该项目的完成给予了极大关怀和方向性的指导。本研究项目得到中国自然科学基金会(项目号: 49972073)的资助。郑州矿产综合利用研究所和地质科学院岩矿测试研究所, 为选矿和测试做了很多工作。在 1996~1997 年野外工作过程中, 西藏自治区地质矿产局、第二地质队和罗布莎铬铁矿山领导及有关同志均给予了鼎力相助。在此一并致以由衷的感谢!

本书有错误之处, 请读者指正。

——作者

1999 年 12 月

Origin of Podiform Chromitites, Diamonds and Associated Mineral Assemblage in the Luobusa Ophiolite, Tibet

(Extended Abstract)

Bai Wenji¹ Zhou Meifu² P. T. Robinson³
Fang Qingsong¹ Zhang Zhongming¹ Yan Bingang¹
Hu Xufeng³ and Yang Jingsui¹

1. Geology of the Luobusa Ophiolite

In Tibet, diamonds in podiform chromitites were reported in two ophiolite belts: the Bonggong-Nujiang and Yarlungzangbu belts. The Luobusa ophiolite lies in the Yarlungzangbu belt which formed during the collision between Eurasia and India around 41 Ma. The ophiolite is tectonically bounded by the Triassic flysch on the south and by the molasse deposits of the Tertiary Luobusa formation and the Gangdese Batholith on the north. The ophiolite is composed of a mantle sequence, a transition zone and an ophiolitic melange. The boundaries between the major units generally dip southward, possibly indicating that the section is overturned or that each unit is an individual thrust slice. The transition zone is mainly composed of dunites with abundant wehrlites. Wehrlites, pyroxenites, gabbros, pillow lavas and cherts in the melange zone are set in a strongly serpentinized, ultramafic matrix.

2. Petrology and Geochemistry

The mantle sequence of the Luobusa ophiolite consists of harzburgites and Di-harzburgites with abundant dunites and podiform chromitites. Harzburgites show porphyroclastic textures, whereas dunites are equigranular. The dunites occur as dykes or lenses in the harzburgites or as envelopes surrounding chromitite bodies. The chromitites have nodular, massive and disseminated textures. Silicate minerals in chromitites are chiefly Ol with minor Cpx and variable amounts of Opx. The mantle peridotites have experienced three stages of deformation. High-temperature recrystallization occurred along the porphyroclasts of Ol or pyroxenes, possibly during the formation of the podiform chromitites. This recrystallization overprinted the "fertile" mantle microstructure and was, in turn, overprinted by a high-stress deformation. This second stage of deformation is characterized by intracrystalline extinction band morphology of Ol and Opx slip system and exsolution along the slip planes. During up-

1. Institute of Geology, Chinese Academy of Geological Sciences, Beijing, China

2. Department of Earth Sciences, University of Hong Kong, Hong Kong, China

3. Centre for Marine Geology, Dalhousie University, Halifax, Nova Scotia, Canada

lift, these rocks experienced a third, mid-crustal level, dynamic deformation. This stage of deformation is marked by the development of deformation lamellae along slip planes and mini-kinking of Ol and recrystallization along kinks of Ol. This succession is very similar to what has been described for orogenic garnet peridotites regionally associated with eclogites.

Harzburgites ($Mg^{\#} = 89$ to 91) are depleted in Ca and Al and are essentially residual rocks. Chromitites, which formed by crystallization from magmas, have a distinctly different chemical trend from the harzburgites, whereas dunites follow the two chemical trends defined by both the harzburgites and chromitites. The harzburgites have unfractionated PGE patterns, but the chromitites and dunites have PGE patterns depleted in Pt and Pd. The chromitites have lower Pd/Ir but higher V, Zn, Cr, and Mn contents than the harzburgites. The dunites have Pd/Ir ratios intermediate to the harzburgites and chromitites.

Chromites in the harzburgites have large variations in $Cr^{\#}$'s (18 to 66) and low Ti contents (<0.15 wt% TiO_2) but those in the chromitites are relatively uniform in $Cr^{\#}$'s (74 to 82) and have high Ti contents (0.2 wt% TiO_2 on average). The dunites contain chromites intermediate in composition between those of the harzburgites and chromitites. The harzburgites have Ol (Fo=90 to 92), Opx (En=87 to 92), and Cpx ($Mg^{\#} = 44.5$ to 53). Silicates in the chromitites have the highest Mg contents. In the reaction zone, $Cr^{\#}$'s of chromites, Fo of Ol, En of Opx and $Mg^{\#}$'s of Cpx increase from Di-harzburgite to harzburgite to dunite to chromitite, suggesting that the parental magmas for the chromitites were not in equilibrium with the harzburgites. In addition, both Opx and Cpx in the chromitites have much lower Ca and Al than those in the harzburgites. The low-Ca and low-Al pyroxenes in the chromitites suggest that they crystallized from a boninitic magma.

3. Mineralogy of Diamonds and Associated Minerals

3.1 Mineral separation procedures

In 1996, we collected a 1500kg sample of chromite from orebody 31 in the Luobusa ophiolite as part of a study of diamonds in chromitites. In order to eliminate possible sources of contamination the samples were removed directly from orebody, carefully washed, air dried and then crushed to pass a 1cm sieve. Mineral separation was carried out at the Zhengzhou Institute of Multipurpose Utilization of Mineral Resources, China.

The alloy minerals were handpicked from several mineral fractions and were then mounted in epoxy, machine polished, and analyzed with a SEM 505 scanning electron microscope and a DEA 9100 energy dispersive spectrometer at the Beijing General Research Institute of Mining and Metallurgy, Department of Process Mineralogy. The operating conditions were an acceleration voltage of 15kV, a beam current of about 12nA, and a takeoff angle of 35°. The program SW9100 NOST was used to analyze the spectra. In a few cases, pure element metals were used as standards to check the results.

3.2 Diamonds

Twenty five grains of diamonds have been recovered from the chromite samples collect-

ed from Orebody 31. Unbroken diamond crystals are typically colorless, euhedral octohedral ranging in size from 0.2 to 0.7 mm. There are also irregular grains and broken fragments. X-ray diffraction analyses and Raman spectroscopy have been used to confirm the visual identification. A few grains contain small inclusions and one grain contains three, relatively large, silicate inclusions. The inclusions are dark green in color and have Raman spectra similar to that of serpentine. However, microprobe analyses of the inclusions indicate an anhydrous composition close to that of clinoenstatite but with somewhat higher SiO_2 . The diamonds comprise a mixed IaA-IaB population that probably had slightly different thermal histories in the mantle. Total nitrogen contents range from about 20×10^{-6} to 670×10^{-6} and aggregation states are up to about 80%. These aggregation states are relatively high and are similar to many diamonds from kimberlites. Temperatures if nitrogen aggregation range from about 1250 °C to 1170 °C from mantle residence times between 50 to 1000 m. y., respectively. Based on the age of the ophiolite, the maximum mantle residence time of these diamonds would have been about 80 m. y..

The evidence presented confirms the presence of UHP minerals in the podiform chromitites of the Luobusa ophiolite. Natural contamination is ruled out because we selected massive chromitite samples directly from pods and veins well below the original ground surface and because of the absence of any other diamond-bearing rocks in the region.

3.3 Associated minerals

Besides diamonds, mineral separates from Orebody 31 include native elements (C, Cu, Fe, Ni, Si, and Cr), carbides (SiC, CrC), alloys (Fe-Si, Fe-Ni, Ag-Au), PGM, sulfides, sulfates and carbonates.

Unique alloy minerals (UAM) from the podiform chromitites in the Luobusa ophiolite, southern Tibet, China, were studied by electron microprobe. They are Os-Ir-Ru, Pt-Fe, Si-Fe, Ir-Ni-Fe, and Fe-Ni-Cr alloys with highly variable compositions, and native Si. The UAM were recovered from heavy mineral separates of the chromitites. Some are attached with chromite fragments. Their sizes range from 0.1 to 0.5 mm. The UAM in the Luobusa chromitites were interpreted as exotic materials from the lower mantle. They were carried up by rising plumes to shallow depths of the upper mantle, then captured by melts from which the Luobusa chromitites crystallized, and finally incorporated into the chromitites.

4. Petrogenesis and Tectonic Significance

Based on their textural relationships, chemical compositions and mineral assemblage, we suggest that the diamonds, Os-Ir-Ru, Pt-Fe, Ir-Ni-Fe and Si-Fe alloys and native Si in the Luobusa chromitites are xenocrysts derived from the deep mantle. We believe that they originated at or near the mantle transition zone and were then carried to shallower depths by a rising plume where they were captured by melts from which chromitites crystallized. Due to their highly refractory character, they remained as solid phases in the melt and were incorporated as inclusions in chromites during chromitite precipitation.

The common association of PGE alloys and sulphides as composite inclusions in chromites, can be explained by epitaxial growth of sulphides on PGE alloy crystals during chromitite crystallization. Because of their similar chemistry and structure, the captured primitive deep mantle alloys would tend to attract platinum-group elements in the melts. During chromitite crystallization, PGE sulphides would crystallize on the PGE alloys.

During emplacement of the ophiolites, some of the alloys were exposed along fractures in the chromites and were altered to form BM alloys and BM-bearing Os-Ir-Ru alloys by desulfurization of PGE sulphides.

During the early stages of evolution of Earth, PGE alloys and natural elements formed from mantle magmas at high temperature, high pressure and highly reducing conditions. Most of them were fractionated into the core because their high density. We argue that some of these remained in the where they were transported to shallow where they were captured by boninitic melts and eventually incorporated into the podiform chromitites.

Acknowledgements: This work was supported financially by NSERC (Canada)-NSFC (Natural Science Foundation of China) bilateral exchange grants to Bai Wenji and P. T. Robinson. Additional funding was provided by the former Ministry of Mineral Resources of China to Bai Wenji and a Hong Kong RGC (HKU7120/97P) grant to Zhou Meifu.

目 录

第一章 区域地质和蛇绿岩地质特征	(1)
1.1 区域地质构造特征	(1)
1.2 蛇绿岩带地质特征	(2)
1.3 罗布莎蛇绿岩块地质概述	(3)
1.4 罗布莎蛇绿岩块的岩相特征	(3)
第二章 罗布莎蛇绿岩岩石学特征	(5)
2.1 蛇绿岩的主要岩石类型	(5)
2.2 岩石结构、构造特征	(6)
2.3 岩石化学和地球化学主要特征	(8)
2.4 地幔斜辉辉橄岩成因讨论	(19)
第三章 罗布莎铬铁矿床特征	(28)
3.1 含铬铁矿矿床的岩相带的地质特征和含矿部位	(28)
3.2 主要工业矿床的矿体形态、产状特征	(29)
3.3 次要铬铁矿床产出特征	(32)
3.4 铬铁矿矿石类型及结构、构造特征	(32)
3.5 罗布莎铬铁矿、金刚石及某些高压矿物的形成条件	(33)
3.6 罗布莎铬铁矿床的成因	(40)
3.7 铬铁矿找矿标志	(43)
第四章 罗布莎铬铁矿中金刚石及伴生矿物特征	(46)
4.1 金刚石及伴生矿物的选矿试验	(46)
4.2 罗布莎金刚石特征	(49)
4.3 与金刚石共生的某些矿物特征	(51)
第五章 讨论与结论	(67)
5.1 实验室合成高压矿物研究的启迪	(67)
5.2 天然超高压矿物组合研究近况与未来	(68)
5.3 不寻常的矿物组合	(69)
5.4 几点结论	(70)
附表 罗布莎金属矿化学成分及分子式	(72)
附图 罗布莎铬铁矿矿化物镜检图片	(81)
参考文献	(88)

Contents

Chapter 1 Regional geology and character of the ophiolite belt	(1)
1.1 Regional geology	(1)
1.2 Character of the ophiolite belt	(2)
1.3 Geological background of the Luobusa ophiolite massif	(3)
1.4 Rock phases of the Luobusa ophiolite sequence	(3)
Chapter 2 Petrology of the Luobusa ophiolite	(5)
2.1 Type of rocks of the Luobusa ophiolite	(5)
2.2 Texture and structure of the rocks for the ophiolite	(6)
2.3 Petrochemistry and geochemistry for the ophiolite	(8)
2.4 Origin of the mantle peridotites	(19)
Chapter 3 Chromite ore deposits in Luobusa	(28)
3.1 Characteristics of chromite ore bodies-bearing rock phase	(28)
3.2 Forms and mode of occurrence of the orebodies for economic value	(29)
3.3 The attitude of orebodies for a minor industrial value	(32)
3.4 Texture and structure of chromite ores	(32)
3.5 Forming conditions of chromite ore, diamonds and some associated high-pressure minerals in Luobusa	(33)
3.6 The origin of chromite ore deposits from the Luobusa ophiolite	(40)
3.7 The indicators of prospecting and exploration for chromite ore deposits	(43)
Chapter 4 The characters of diamonds and their associated minerals from the Luobusa chromite ores	(46)
4.1 Concentration of the diamonds and associated minerals from the chromite ores in Luobusa	(46)
4.2 Characteristics of diamonds	(49)
4.3 Characteristics of some minerals associated with diamonds	(51)
Chapter 5 Discussion and conclusion	(67)
5.1 Direction of experimental investigation of the theoretical high pressure minerals	(67)
5.2 Recent and future for investigation of native ultrahigh pressure minerals.....	(68)
5.3 unique and undetermined association of mantle minerals	(69)
5.4 Conclusions	(70)
Attached table: Alloy chemical compositions from Luobusa	(72)
Plate of printing photo	(81)
References	(88)

第一章 区域地质和蛇绿岩地质特征

1.1 区域地质构造特征

在西藏, 目前已知含金刚石的蛇绿岩带有二条, 即藏南雅鲁藏布江蛇绿岩带和藏北班公湖-怒江蛇绿岩带。由于雅鲁藏布江蛇绿岩带的地质条件和生活条件便于开展工作, 同时也由于人力和物力所限, 本项目仅以藏南雅鲁藏布江岩带的罗布莎岩块作为主要研究对象。罗布莎岩块的岩石新鲜, 很少或几乎没有遭到蛇纹岩化, 这不但便于野外取样选矿, 同时, 岩石矿物的原生结构构造十分清楚。这就为探讨其成因、演化和岩石形成过程中的物理化学条件和深部地质环境, 提供了更有价值的信息。

藏南罗布莎蛇绿岩分布在印度河-雅鲁藏布江缝合线的东端 (图 1-1)。

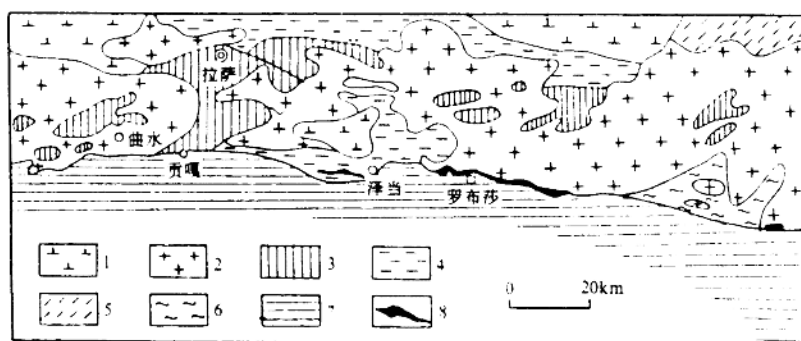


图 1-1 西藏雅鲁藏布江缝合线东段及罗布莎蛇绿岩

Fig. 1-1 The eastern section on the Yarlung Zangbu Suture of Southern Tibet and ophiolite

1. 林芝组; 2. 冈底斯岩基; 3. 中三叠统; 4. 早白垩统; 5. 早古生界;

6. 变质片麻岩; 7. 晚三叠复理石; 8. 蛇绿岩块

1. Linzizhong (Formation); 2. Gangdessa batholith; 3. Mid-Triassic strata; 4. Early Cretaceous strata;

5. Early Palaeozoic strata; 6. Metamorphic rocks; 7. Late Triassic flysch; 8. Ophiolite

在青藏高原, 最南部的两条缝合线内蛇绿岩均具有铬铁矿化。雅鲁藏布江缝合线代表中生代冈瓦纳板块内部的缝合线, 是喜马拉雅特提斯海的最后闭合带。以蛇绿岩带为界, 南部为印度地块北缘的复理石及混杂岩带, 北部为陆缘山前磨拉石和冈底斯-念青唐古拉火山岩浆岩带。火山岩浆带的北部为晚白垩世复理石建造 (日喀则群), 下伏含放射虫硅质岩和熔岩。在蛇绿岩带南侧, 发育有一条宽达 10~50km 的混杂堆积, 混杂带南侧为晚三叠世复理石。混杂堆积带比较复杂, 它甚至包含早二叠世生物灰岩。混杂岩块规模大小不等, 大者在雅鲁藏布江可达数公里宽。缝合带内除含有二叠系等岩块的混杂岩断续出露外, 尚发现有三叠纪放射虫硅质岩 (郭铁鹰等, 1991)。本区所见十分发育的三叠纪大陆边缘沉积, 说明海盆当时已成为开阔的海域, 同时可能还有相对应的洋壳发育。从三叠-早侏罗世到早中白垩世, 可能曾出现过后来被消滅的规模不等的深海盆地。由于蛇绿岩同位素年龄资料十分有限以及出现

不同时代的放射虫硅质岩, 因而对蛇绿岩块主要形成时代问题尚没有统一的认识。

雅鲁藏布江缝合带的缝合时间。如果以蛇绿岩块上陆产生变质作用的时间为准, 应为 81Ma 左右 (王希斌等, 1987)。在缝合之后, 发育有一条追踪蛇绿岩带分布的磨拉石带。它不整合覆盖在蛇绿岩块和上侏罗一下白垩世地层之上, 厚约 200~1000m, 并含大量蛇绿岩成分的砾石, 称为柳区砾岩, 时代为老第三纪 (E)。此外, 沿雅鲁藏布江还分布有另一条磨拉石带不整合于著名的冈底斯火成岩系之上, 时代为第三纪 (E—N)。这些事实表明, 缝合带形成之后, 雅鲁藏布江地带仍然处于低凹的盆地环境, 并接受了来自近旁的较高地形的剥蚀物。这就证明, 当时在缝合带或板块碰撞带内并没有形成山脉, 山脉形成与板块碰撞无关 (白文吉、胡旭峰、杨经绥和周美付, 1993)。西藏高原的隆升时间是第四纪。柳区砾岩发生褶皱和变形, 说明第四纪时沿缝合线的地层曾受到较强烈的挤压作用。

按板块构造构思, 前三叠纪在冈瓦纳大陆和塔里木地块之间曾存在过古特提斯洋, 三叠纪即在冈瓦纳大陆内产生新特提斯洋, 而古特提斯洋即随之消减。到侏罗—白垩纪, 新特提斯洋扩大, 而古特提斯洋则完全消减。早第三纪开始, 印度洋形成, 而新特提斯洋被消减并抬升为青藏高原。由塔里木—柴达木地块向南, 古特提斯洋被新特提斯洋渐次代替, 即新洋盆通过扩张而成长, 而古大洋则通过消减而消失。青藏高原上这种板块构造格架几乎被地质界完全接受, 因此, 有关本区地质构造问题不再赘述。

1.2 蛇绿岩带地质特征

青藏高原存在数条时代不同的蛇绿岩带 (白文吉等, 1986; 肖序常, 1984; 王希斌等, 1987; 李春昱, 1982; 李锦轶, 1996)。如前所述, 其中已知赋存有铬铁矿床并含金刚石的蛇绿岩带为斑公湖—怒江以及雅鲁藏布江蛇绿岩带。

斑公湖—怒江蛇绿岩带西起斑公湖, 东至怒江, 长约 1500km。沿该带分布有较多的蛇绿岩组分的岩块和混杂堆积体。在东巧区附近, 亏损地幔橄榄岩、堆积岩和火山岩发育。在藏北斑公湖地区, 有由超镁铁地幔岩、辉长岩、堆积岩和枕状熔岩等组成的岩块, 长达 100km。蛇绿岩块仰冲到侏罗纪复理石上并有早白垩统沉积岩伴生和覆盖。东巧蛇绿岩块的仰冲作用发生在中侏罗世。在安多地区, 发现有由仰冲引起的、年龄为 172Ma 的片麻质岩石 (Xao et al., 1985), 因而古大洋最后关闭时间应为早白垩世 (郭铁鹰等, 1991)。

印度河—雅鲁藏布江蛇绿岩带, 东自波马, 西到拉达克, 长约 2000km。在中段日喀则地区, 蛇绿岩块发育。罗布莎含铬铁矿和金刚石的蛇绿岩块即分布在该带东部, 该岩块平行于雅鲁藏布江呈 S 型折曲状展布, 被南北向平移断层错开。较详细找矿地段位于罗布莎村。此地段过渡带的纯橄岩已被并到堆积杂岩相内。罗布莎蛇绿岩块的岩相—构造图见图 1-2。

日喀则蛇绿岩块沿印度河—雅鲁藏布江缝合线分布, 连续长达 170km, 其上被硅质岩 (燧石) 和远洋沉积层覆盖, 其下为枕状熔岩和块状熔岩, 并向基性岩墙和岩床过渡, 最下部为地幔斜辉辉橄岩和纯橄岩杂岩带, 为典型蛇绿岩组合。

印度河—雅鲁藏布江蛇绿岩带代表了中白垩世 (110~100) Ma 大洋, 这是根据直接覆盖在日喀则蛇绿岩块上的硅质岩放射虫得出的 (Marcoux et al., 1982)。它和来自日喀则蛇绿岩块的 U-Pb 同位素年龄 (120 ± 10 Ma) 以及 Nd/Sm 同位素年龄 (109 ± 21 Ma) 基本近似 (Gopel et al., 1984; Prinzhofer, 1987; Nicolas, 1989)。根据古地磁资料, 在印度河—雅鲁藏布江缝合线一带, 印度大陆的最后缝合时间, 大约在 50Ma (Patriat and Achache, 1984)。蛇绿岩块上陆大约在始新世 (40Ma) 以前。冈底斯地区最年轻的花岗闪长岩为 41Ma, 代表

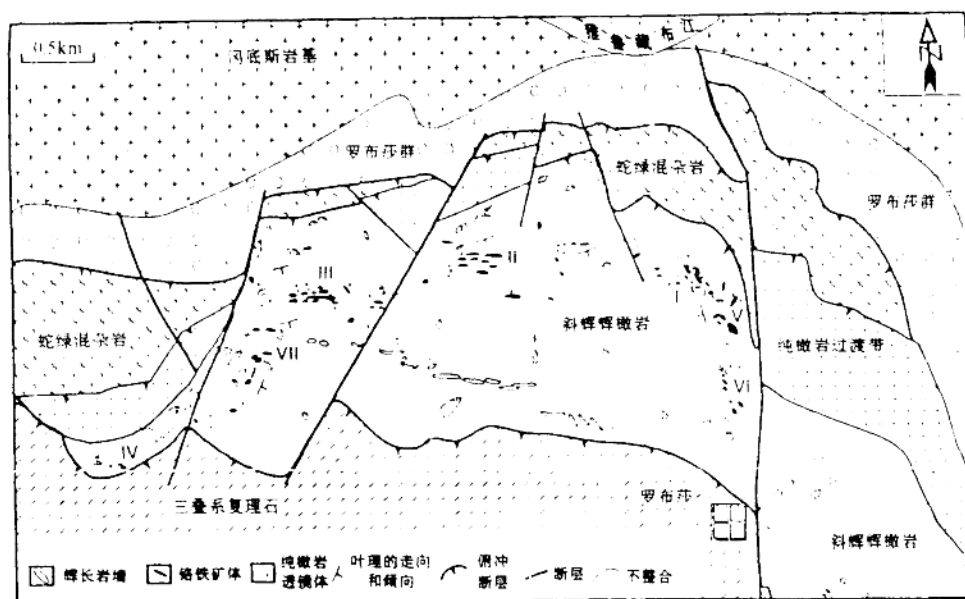


图 1-2 罗布莎蛇绿岩地质图

Fig. 1-2 Geological map of the Luobusha ophiolite

大洋最晚消减时间 (Sharer et al., 1984)。印度河—雅鲁布江缝合带内的蛇绿岩套层序较完整和清晰, 这将在下面各章节中予以叙述。

1.3 罗布莎蛇绿岩块地质概述

含豆荚状铬铁矿和金刚石的罗布莎蛇绿岩块出露于印度河—雅鲁藏布江缝合带的东段 (图 1-2), 位于日喀则岩块东侧。岩块中大部分地幔橄榄岩和堆积岩出露良好, 岩块的北侧分布有冈底斯花岗岩岩基和第三纪磨拉石建造, 并与蛇绿岩块主要呈断层接触。岩块南侧, 主要为泥砂质钙质沉积和基性火山岩组成的三叠纪复理石, 地层韵律清晰, 交错层和印模发育。地层倾向南, 倾角 $50^{\circ} \sim 60^{\circ}$, 其中褶皱发育, 含有较丰富的动物化石。按化石资料, 罗布莎岩块南侧的三叠系相当于上三叠统诺利克阶。在罗布莎蛇绿岩块的变质橄榄岩-堆积岩带北侧, 有早白垩世海相火山-碎屑岩断续出现, 它在龙给曲两岸厚度可达 $200 \sim 300\text{m}$ 。与第三系呈断层接触并逆冲于第三系之上, 有的地方还逆冲于三叠系之上。在罗布莎蛇绿岩块西部发育蛇纹混杂岩, 即在蛇纹岩中含有大量基性火山岩、硅质岩等构造岩块。局部地带可见第三纪磨拉石不整合覆盖在蛇绿岩块之上。

1.4 罗布莎蛇绿岩块的岩相特征

罗布莎蛇绿岩由于构造破坏, 层序不全, 因而未见完整的蛇绿岩剖面。罗布莎蛇绿岩块总体呈近东西向展布, 西起尼色拉, 经罗布莎、康金拉, 东至加查, 全长约 41km , 西部宽, 东部窄。在香嘎山一带最宽可达 3.7km , 而在罗布莎地段宽约 2km , 总面积 70km^2 以上。从剖面上看, 岩块总体向南倾斜, 北侧接触面产状较缓, 南侧较陡。

罗布莎蛇绿岩块主要由地幔橄榄岩、堆积带的纯橄榄岩、单斜辉橄岩-辉石岩-辉长岩杂岩以及蛇纹混杂岩组成 (图 1-3)。但堆积岩、玄武质熔岩和燧石一般均被构造破坏形成混杂堆

积。在藏朗曲东坡堆积杂岩较发育，主要由单辉辉橄岩、辉石岩和辉长岩组成（图 1-3）。整个蛇绿岩块或推覆到罗布莎第三纪磨拉石建造之上，或推覆到冈底斯岩基上。与此同时，南部三叠纪复理石建造又推覆到蛇绿岩块的地幔橄橄榄岩相之上。但主要层序的界面仍是倾向南的。堆积带的纯橄岩相和堆积杂岩交替重复出现，乃是由推覆的岩片叠覆而成的。

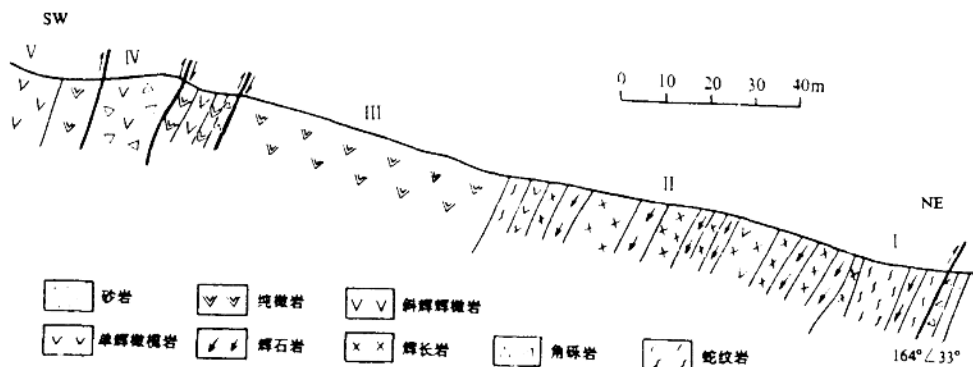


图 1-3 罗布莎蛇绿岩块堆积杂岩剖面（据西藏地质局铬矿综合研究队，1979）

Fig. 1-3 Petrographic section of cumulative sequence for Luobusha ophiolite

I. 主要为蛇纹混杂岩, II. 堆积杂岩, III. 堆积纯橄岩, IV. 角砾岩带, V. 地幔橄橄榄岩

I. Serpentine melange, II. Cumulate complex, III. Cumulate dunite, IV. Breccia zone, V. Mantle peridotite

从岩块北部边界起，沿藏朗曲可把岩块分成 5 个岩相带：I—蛇纹混杂岩带，为一伴随有蛇纹岩夹辉石岩和辉长岩（来自堆积带）厚约数米的角砾岩带；II—堆积岩带，由宽约数米到 10m 左右的辉石岩、辉长岩和单斜辉石橄橄榄岩组成，堆积层理较发育，岩石堆晶构造明显，岩相带厚度在藏朗曲约 300m；III—过渡带由纯橄岩组成，它与堆积杂岩呈过渡关系。纯橄岩相宽约数百米，其中含有稀疏浸染状铬铁矿化；IV—为堆积岩带的构造岩片，岩相带由辉长岩、辉石岩相间组成，具有堆积岩特点，宽仅 30~100m，其上部为角砾岩带；V—是罗布莎蛇绿岩块的主体部分，由地幔斜辉辉橄岩和二辉橄橄榄岩组成。岩相带宽 500~1500m。西段呈一向北突出的弧形，北侧与堆积纯橄岩呈过渡关系，南侧与三叠系呈断层接触。该岩相内含有纯橄岩脉（异离体），大多为透镜状，脉状和不规则状，岩脉规模大小不等，长约 1m 至数十米，宽数厘米至 1~2m。纯橄岩脉常与铬铁矿体伴生，且主要分布于该岩相中部。V 岩相是含工业铬铁矿床和金刚石的岩相。除上述 5 个岩相带外，还见有辉长岩脉星散分布于地幔橄橄榄岩相内，长度可达数百米，宽 10~20m，明显切割橄橄榄岩的叶理。特别应指出的是，第 III 岩相带（图 1-3）纯橄岩和第 IV 岩相带纯橄岩均具有堆积岩特点，它与单辉橄橄榄岩（Wehrlite）呈过渡关系，主要由粗粒橄橄榄石和少量单斜辉石组成，自形细粒铬尖晶石呈包体分布于橄橄榄石中，但有时呈层状分布。单斜辉石为他形晶分布在橄橄榄石颗粒间，而橄橄榄石多为自形晶，且为等粒的。显然，第 III、IV 岩相带的纯橄岩产于地幔橄橄榄岩相与互层状堆积岩相的过渡带内，在剖面上二次重复出现乃是由于逆断层推覆的结果。

第二章 罗布莎蛇绿岩岩石学特征

2.1 蛇绿岩的主要岩石类型

罗布莎蛇绿岩块，除北部蛇纹混杂岩外，其余部分只遭受过轻微或几乎没有遭受过蛇纹石化，因此，它是研究地幔橄榄岩和某些堆积岩原生结构和原生矿物极有利的场所。组成蛇绿岩块的主体为地幔橄榄岩。地幔橄榄岩相内含有具工业意义的豆荚状铬铁矿和高压矿物金刚石。所以地幔橄榄岩、铬铁矿床和金刚石及其伴生矿物，是本项目研究的重要对象。

地幔橄榄岩的岩石种类命名是以橄榄石(Ol)、斜方辉石(Opx)和单斜辉石(Cpx)的百分含量为基础的(Streckeisen, 1973)。纯橄岩是指由90%以上的橄榄石和不足于10%的辉石(Pyr)组成的岩石，而斜辉辉橄岩(Harzburgite)则主要指由橄榄石、斜方辉石及不超过5%单斜辉石组成的岩石，等等。本文有关这些岩石的分类命名如图2-1所示。

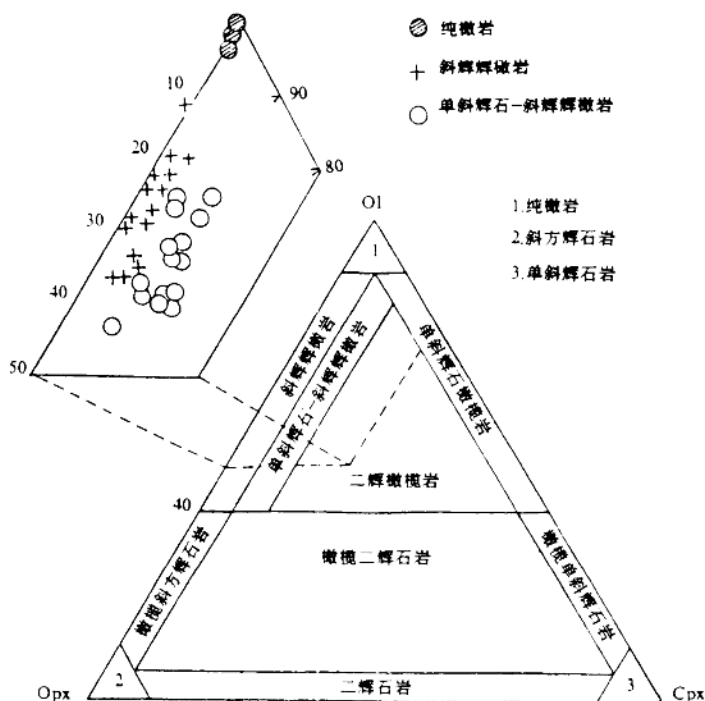


图 2-1 罗布莎地幔橄榄岩的矿物含量统计投点及 Opx-Cpx-Ol 岩石分类图解

Fig. 2-1 Plots of mantle peridotites in Luobusha on Opx-Cpx-Ol diagram, classification of ultramafic rocks (After Zhou Meifu, 1995)

薄片矿物成分的统计结果表明，罗布莎蛇绿岩的地幔橄榄岩主要为斜辉辉橄岩(Harzburgite)，其中含62%~86%橄榄石、11%~32%斜方辉石、1%~5%单斜辉石以及

0.2%~1.1%铬尖晶石(周美付, 1995)。单斜辉石斜辉辉橄岩(Di-Harzburgite)则指那些含有5.9%~9.9%,有时可达12%单斜辉石的斜辉辉橄岩(图2-1)。纯橄岩一般可含1%~3%斜方辉石,0.0%~0.7%的单斜辉石和0.3%~1.0%的铬尖晶石。按照 Strecklisen(1973)分类,罗布莎岩块没有真正的二辉橄岩(Lherzolite)。

2.2 岩石结构、构造特征

2.2.1 斜辉辉橄岩

在罗布莎地幔橄橄岩相内,新鲜的、没有或几乎没有蛇纹石化的斜辉辉橄岩到处可见,原生结构和构造十分清晰。新鲜岩石质地坚硬,呈灰绿色,具中-粗粒结构。风化面上辉石常呈斑状凸起。由于其粒径大小不一和分布不均,因而形成碎斑状构造和粗糙的表面。

镜下观察,斜辉辉橄岩普遍具有熔融代替结构(Melt-replaced texture),即第一世代矿物被部分熔融,所熔化的空间被第二世代矿物充填所形成的结构(图版Ⅰ、图a)。在罗布莎斜辉辉橄岩中的大部分斜方辉石均在不同程度上被橄榄石等矿物或其集合体代替,致使斜方辉石边缘具有复杂的港湾状或蚕食状形态。有的第一世代橄榄石或斜方辉石甚至被第二世代矿物熔融分割成若干互不相连的孤岛状块体。有时,第二世代橄榄石沿第一世代斜方辉石的解理代替或楔入(图版Ⅰ,图b)。除第二世代橄榄石熔融代替第一世代斜方辉石外,也有橄榄石代替橄榄石,斜方辉石代替斜方辉石的现象。因而罗布莎斜辉辉橄岩具有两个世代橄榄石和斜方辉石。这种熔融代替结构曾于1976年发现,但当时只简单称为交代结构^①。熔融代替结构表明,地幔橄橄岩曾经历过局部熔化作用,被熔化的矿物至少有橄榄石和辉石,熔化出的熔体成分以橄榄石质为主,所以橄榄石代替辉石的现象最为普遍。有时也见有橄榄石、斜方辉石和铬尖晶石集合体代替斜方辉石的现象。这就表明,这里的熔融代替作用不同于一般的交代作用。熔融代替结构为地幔橄橄岩的一种原生结构,是罗布莎橄橄岩块中普遍存在的重要的岩石结构特点。在糜棱岩化地带、大型或显微剪切带和挤压带内,熔融代替结构常常被破坏,同时发生次生结构的干扰和叠加。此外,之所以认为熔融代替结构为原生结构,是由于第一和第二世代矿物均具有肯克带(Kink-banding),也就是说,熔融代替作用发生于肯克带产生之先。

斜辉辉橄岩大多显示有不同程度的剪切变形,形成变斑状结构(Porphyro-clastic texture),类似于 Mercier 和 Nicolas (1975)所展示的结构。橄榄石和辉石变斑晶(Porphyroclasts)的粒径多在0.5cm或更大,基质橄榄石和辉石均为细粒的,粒度为0.01~0.05cm,这些细粒矿物分布于粗粒变斑晶的周围。细粒矿物组成三联点结构或呈多边形外形,具有全部或部分重结晶特点。细粒相矿物不具肯克带等变形结构,但具有直线型的边界。大的变斑晶具肯克带或呈碎裂状,有时亚颗粒产生了旋转。在显微剪切带内,有时矿物完全细粒化而没有重结晶,形成条带状泥土或糜棱岩。显然,普遍分布的肯克带、变形纹、波状消光等现象的产生早于糜棱岩化、重结晶作用和碎裂作用,前者可能是由于深部地幔塑性变形作用的结果,后者则可能是由于更晚期的剪切作用造成的。也就是说,原生矿物的肯克带、变形纹、机械双晶、波状消光是在深部地幔的塑性变形环境产生的,而碎裂、糜棱岩化和重结晶现象,则是在规模不同的剪切带内剪切作用的产物。

在罗布莎斜辉辉橄岩的斜方辉石中,常常有出溶的单斜辉石晶片沿其解理分布。这表明,

① 西藏铬铁矿综合研究队,罗布莎矿床组年度报告,1975。