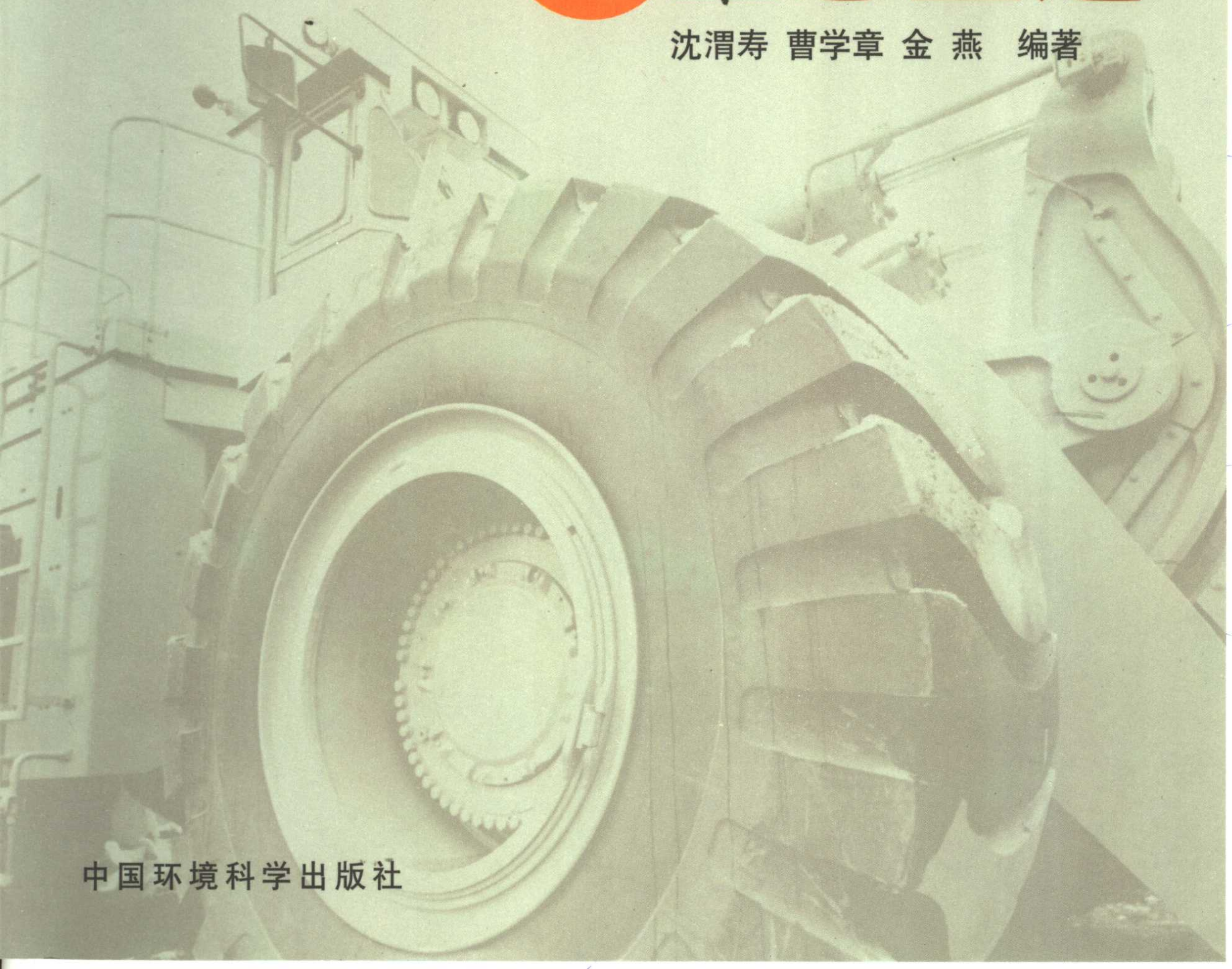
KUANGQU SHENGTAI POHUAI YU SHENGTAI CHONGJIAN

矿区生态破坏与生态重建

沈渭寿 曹学章 金 燕 编著



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前　言

我国矿产资源丰富，截至1995年底，全国已发现的矿产有168种，有探明储量的矿产151种，分布于2万余处。据初步评估，矿产资源潜在总值居世界第三位，20多种矿产在世界上具有优势地位。据1995年统计，全国固体矿石产量达51.2亿t，煤炭13.6亿t，原油1.5亿t，天然气179.0亿m^3，矿业总值4 636亿元。煤炭、水泥产量居世界首位，化肥居第二位，钢和有色金属居第三位，原油居第五位，黄金居第六位。中国已成为世界重要的矿产资源大国和矿业大国。

然而，在矿业取得巨大成就的同时，我国矿区生态环境也普遍受到严重破坏。1980年代后期以来，矿区生态重建逐步受到各级政府和矿山企业的重视，已有不少矿区开展了采矿废弃地的生态重建工作。但是，我国矿区生态重建中还存在不少问题，其中最重要的问题之一，就是理论和技术的支撑还较薄弱，行之有效的、成熟的技术还较少。在有色金属矿区，这一问题更为严重，制约了我国有色金属矿区的生态重建。为此，在国家环境保护总局1998年度科技发展计划中，列入了《矿区生态环境重建技术试验研究》。该项目旨在通过点上试验观测与面上调查研究相结合的方法，对我国南方有色金属露天矿区生态重建技术现状进行系统总结；针对主要问题，选取试验基地进行试验研究；在总结现有研究成果和本项目试验的基础上，编制有色金属露天矿区生态重建技术规范。本书是在该研究成果的基础上编写而成的。

张纪伍同志在本研究中参与了部分试验工作，江西省铜业公司德兴铜矿环保卫生部熊报国、占幼鸿、赖志满、胡声泰和江西省德兴县环境保护局叶德华、程琦等同志也为本项研究中的试验提供了大力帮助，作者在此深表感谢！

作　者

2004年5月于南京

摘　要

一、矿山开采生态环境破坏现状

1. 矿区生态破坏的总体评述

从总体来看，我国矿产资源开发造成的生态环境问题表现为以下四个方面：

1）采矿占用和破坏土地。包括露天矿开采挖损土地，废石场（排土场）、尾矿场、矸石山压占土地和地下开采造成的地面塌陷。

2）造成水土流失、滑坡、泥石流、崩塌等次生地质灾害。

3）污染生态环境，造成生态失调。采矿和选矿废水排入地表水体（河流或湖泊）后造成矿区地表水体的有机污染和重金属污染；采矿剥离的含硫化合物的岩石以及矿山大量堆积的废渣和尾矿，经长期与雨水、空气接触，氧化渗漏出含重金属的酸性水，造成地表水体和地下水体的严重污染；矿山疏干排水，使地下水位下降，出现大面积疏干漏斗，使地表水和地下水的动态平衡遭到破坏；使用矿山废水和受酸性淋溶水污染的水体灌溉，使矿区周围农田受到重金属污染，而且往往导致土壤的盐渍化，使土壤肥力下降，功能衰退；矿产开发中排放的废气严重污染矿区的空气，矿山开采中产生的废石尾沙已构成了矿区大气浮尘污染的主要污染源。

4）改变了原来的地表景观，破坏了原有的地表植被，导致土地退化和荒漠化的扩展。

2. 矿区生态破坏的区域特征

从区域特征看，矿山开发造成的生态破坏，在不同的自然地理区表现不同。在西北青藏区，矿山占用和破坏的土地以草地为主；在东北区、华南区、西南区以林地为主；长江中下游区则以耕地为主。华南、西南区露天开采占用的土地大于地下开采占用的土地，西北青藏区、长江中下游区地下开采占用的土地大于露天开采占用的土地。矿山开发对景观的影响，在干旱、半干旱区表现为土壤的风蚀和荒漠化，使土壤层的结构丧失；在湿润地区，如华南、西南、长江中下游地区，表现为水土流失和流域性的酸性废水污染。

我国矿山开发造成的土地破坏呈点状分布，但主要分布在我国的东部、中部地区，这与矿产资源开发的现状一致。在土地破坏面积较大的开采矿种中，北方以煤炭、铁矿为主，南方以有色金属矿为主。

3. 重点矿区生态破坏的特征

重点矿区的生态破坏有以下特点：山西矿区、河南中北部矿区、黑龙江三江平原西缘矿区以煤炭开采破坏土地为主。其中地下开采造成地表塌陷是土地破坏的主要类型。辽宁辽河平原东缘和辽东山地丘陵西缘以铁矿和煤矿的露天开采造成的土地挖损、压占为主。河北东北部矿区主要是铁、金、煤矿露天开采造成的土地挖损、压占和地下开采造成的地表塌陷。兖滕两淮地区是我国东部地区一条重要的煤带，该区生态破坏的特点表现为地下开采造成严重的地表塌陷，是我国塌陷破坏最严重的地区。安徽长江沿岸丘陵山区以铜、铁、硫等矿产开采为主，采矿对生态环境的破坏表现为压占、挖损土地，矿山废水、酸性水对耕地的污染。湘、赣、粤毗邻地区有色金属矿产储量丰富，采矿造成的生态破坏主要表现为露天采矿场对土地的挖损，尾矿场、废石场对土地的压占，矿山污染物对周围水系、土壤的污染。豫、陕接壤地区以金矿开采造成的生态破坏为主，境内的秦岭支脉是我国主要的金矿成矿带，由于采金矿渣的随意堆放，造成严重的生态环境破坏。此外，土法选金产生的含汞废水严重污染水体及下游农田。云、贵、川毗邻地区硫磺等的开采和冶炼造成生态环境的破坏严重，其中土法冶炼导致的土壤污染十分严重。

二、我国矿区的生态重建现状

我国矿区的生态重建始于 1960 年代。到了 1980 年代，我国矿区的生态重建工作进入了有组织、有规模的阶段。目前，我国矿区的生态重建主要在采矿造成的四种破坏类型上进行。这四种主要的破坏类型是露天采矿场、废石场（排土场）、尾矿场（包括采煤中产生的矸石山）和地下开采造成的塌陷区。

1. 露天采矿场采空区的生态重建

在采空区，根据其重建目标，可归纳为四种主要的重建模式。

1）以农林利用为重建目标的农林重建模式，即将采空区充填，平整覆土用于农林利用。根据采空区充填物质的不同，又将其分为剥离物充填、泥浆运输充填和人造土层充填三种重建类型。

2）以发展旅游、渔业开发、水源地、污水处理池为重建目标的蓄水重建模式。

3）挖深垫浅、综合利用的重建模式。

4）露天采矿场边坡以天然植被恢复和人工促进植被恢复的重建模式。人工促进植被恢复的方法有人工补给种源、为创造落种条件进行边坡处理等。

2. 排土场（废石场）的生态重建

排土场（废石场）的生态重建以农林利用为主，所使用的植被恢复技术有：

1）排土场（废石场）稳定技术

为了保证排土场的稳定，建立完善的排水系统；在排土场的边坡建立生物防

护体系；在排土工艺上，采取排土末期进行堆状排土；在排土场平整时，根据重建的目标不同，平整为不同的坡度。

2）排土场土壤改良技术

土壤改良的方法有直接覆盖土壤法和生物改良法。覆盖土壤法即在排土场的表面覆盖一层土壤。覆盖层的厚度依底层岩土的性质和利用目的而定，一般厚度为 10～60 cm，以利于农林业耕种。生物土壤改良包括直接种植绿肥植物、利用生物活化剂、施有机肥以及用化学法中和酸碱性的土壤，以达到土壤改良的目的。此外，从管理方面，采用合理的轮作、倒茬和耕作改土，加快土壤的熟化，增加土壤的肥力。

3）植物种的筛选、种植及配置技术

排土场上植树种草一般采用穴植和播种的方法。穴植即挖穴后带土球栽植或客土造林。根据整地时间的不同，又可分为春整春种和秋整春种。此外，排土场边坡还可采用水力播种、铺设草皮的方法。排土场平台和边坡上植被配置模式有草、草灌、草灌乔三种模式。

根据露天矿废石场（排土场）条件的不同，又可将废石场的重建分为三类：第一类，含基岩和硬岩石较多的废石场的生态重建。此类废石场位于土源缺乏区，由于含有较多的基岩和硬岩不利于植被生存，重建时利用废弃物如岩屑、尾矿、炉渣、粉煤灰、淤泥垃圾等作充填物料，种植抗逆性强的树种。第二类，地表土较少及岩石易风化的废石场的生态重建。此类废石场位于丘陵地带，含表土较少，又难以采集到覆盖的土壤，但其岩石易分化，因此在重建时，稍作平整就可直接种植抗逆性强、速生的林草。第三类，表土丰富的矿区排土场（废石场）的生态重建。此类排土场（废石场）地表土源丰富，重建时直接取土覆盖，进行农林种植。

3. 尾矿场的生态重建

尾矿场生态重建的内容包括尾矿场土壤的改良、植物的筛选与种植以及配置模式的选择。

由于尾矿的机械组成单一，持水持肥力差，pH 呈酸性、碱性，且含有过量的重金属及盐类，对植物的生长定居不利，因此生态重建时必须进行改良。一般对于呈酸性的尾矿，用石灰中和；对呈碱性的尾矿，用石膏、氯化钙作调节剂；对含毒重金属的尾矿，采用铺盖隔离层、覆土的方法。

在植物种选择上，筛选生命力强，耐贫瘠的乡土树种，适当引入外来植物种。

尾矿上植物种植方法有种子直播，也可采用实生苗穴植。配置模式有林草型、草果型、农林型等。

由于尾矿场的条件及各矿山经济条件不同，我国矿山尾矿场的生态重建可分为覆土和不覆土两种类型。不覆土重建的尾矿场多位于土源缺乏的地区，重建时节省了覆土的工程，但可选择的植物种有限，且需要较多的田间管理。覆土重建

的尾矿场位于有土源的地区，覆盖土层厚度一般在50 cm以上。南方矿区土源缺乏，一般将剥离的表土单独存放，待尾矿干涸后，再将其覆盖在尾矿上。

4. 矸石山生态重建

矸石山是煤炭采矿和选矿中产生的废石堆积而成的，也可以作为尾矿的一种。矸石山生态重建以人工绿化为主。目前主要的植被恢复技术有：

1）矸石山整地和侵蚀控制技术。为了解决矸石山机械组成较粗，保水性差的问题，采用穴状整地和梯田整地，在整地的时间上采用秋整春种的方式。

2）酸性矸石山改良技术。为了中和矸石自燃后产生的酸性和强酸性，一般采用 CaO 或 $CaCO_3$，将其破碎后均匀撒入矸石场，用量依矸石的 pH 和中和材料的纯度以及矸石层的深度来定。

3）覆土技术。为了解决矸石山养分贫乏、地表高温的问题，根据矸石山表面的风化程度，分别采用不覆土直接种植、覆薄土（5 ~ 10 cm）、覆厚土（50 cm）的方法。

4）矸石山种植技术。在种植方式上，针对不同的植物种，采用不同的种植方式。对落叶乔、灌木采用少量配土栽植；对常绿树种采用带土球移植；对花草等草本植物采用蘸泥浆和拌土撒播。此外，有些落叶乔、灌木如火炬树、刺槐等，在种植前采用短截、强剪或截干的措施。

5. 塌陷区的生态重建

塌陷区生态重建的目标有农业、建筑、水域（鱼塘、公园、水库）等。不同的塌陷类型采用不同的重建模式。目前重建利用的方向趋向于综合利用。根据塌陷地生态环境破坏的结构类型，塌陷区生态重建模式可以归纳为以下几种：

1）非积水稳定塌陷地农业综合开发模式。将煤矸石、粉煤灰或其他物质（河、湖淤泥）充填于塌陷区内，整平覆土用于农业、林业的种植。此外，也可不充填，直接将塌陷地边坡修整为梯田或坡地重建为保水、保土，农果相间的陆地农田生态系统。

2）非积水稳定塌陷地建筑开发与建筑用地重建模式。

3）季节性积水稳定塌陷地农、林、渔综合开发生态重建模式。采用挖深垫浅的方法，将塌陷下沉较大的土地挖深，用来养鱼、栽藕或蓄水灌溉，用挖出的泥土垫高下沉较小的土地，使其形成水田或旱地，种植农作物。

4）常年浅积水稳定塌陷地渔、林、农生态重建模式。此类塌陷地重建方向以养鱼为主，兼顾发展农林业，重建的工程措施为挖深垫浅。

5）常年深积水稳定塌陷地水产养殖与综合开发重建模式。此类塌陷地除发展渔业外，大面积的深水沉陷地还可以建立水上公园、污水处理场、水库等。

三、国外矿山生态恢复与重建概况

最早开始生态重建的是美国和德国，美国在《1920年矿山租赁》中就明确

要求保护土地和自然环境，德国从1920年代开始在煤矿废弃地上植树。1950年代一些国家的重建区已系统地进行绿化。1960年代许多工业发达国家加速重建法规的制定和生态重建工程的实践活动，比较自觉地进入科学的生态重建时代。进入1970年代，生态重建技术集采矿、地质、农学、林学等多学科于一体，发展成为一门牵动着多行业、多部门的系统工程。生态重建技术的发展和生态重建法规的逐步完善，使这些国家生态重建率明显提高，如美国1970年以前平均生态重建率为40%，1970年联邦土地生态重建法规颁布后，新破坏土地实现了边开采边重建，生态重建率为100%，同时又不断地对废弃的土地进行生态重建。前民主德国从1960年代末到1980年代初，生态重建面积是露天采煤占用面积的92%；联邦德国的莱茵煤矿区，到1985年底生态重建土地面积是露天采煤占地面积的62%，前苏联自1970年代以来生态重建工作得到了很大程度的发展，黑色金属矿山平均年重建率已提高到50%。

四、德兴矿区生态恢复与重建试验

德兴矿区两年的矿山生态恢复试验结果表明，采用的方法和措施得当，可获得良好的效果。

1）采矿场边坡植被恢复

黄牛前边坡（1号试验地）采用带土球移植和直播，栽、播后加强水肥管理，植被恢复很快，取得了良好的效果。

2）排土场边坡、平台植被恢复

杨桃坞排土场边坡（2、8号试验地）和电动轮排土场（3号试验地），在栽、播前对边坡进行处理，打桩固定，加强边坡的稳定性；或修成水平阶，有利于栽播后水肥的管理。试验结果证明，采用以上方法，植被恢复非常成功。5、6、7号试验地由于播前未作边坡处理，幼苗出土后由于日灼和暴雨的冲刷而难以保存，试验失败。因此，栽种前进行边坡处理，是边坡植被恢复的重要保证。

3）尾矿场植被恢复

德兴铜矿1号尾矿场（4号试验地）植被恢复试验结果表明，尾矿场的植被恢复主要取决于选用的先锋植物种。植物种选择得当，在不覆土的情况下，仍然能生长良好。适当覆薄层土，植被恢复速度更快。

4）种植方法的选择是植被恢复的重要保证

矿区土壤具有特殊性，如重金属含量高，土壤贫瘠，尤其是硫化物含量高，当遇到雨水冲刷时，土壤中硫与水反应生成硫酸，造成植物死亡。因此，栽种前进行整地，避免试验地积水，是酸性排土场和尾矿场植被恢复成功的重要保证。堆土栽植法是采矿场和排土场平台植被恢复的有效方法，在矿山植被恢复中具有较好的推广价值。

5）加强栽播后的管理，是矿山植被恢复的重要环节

特别是栽种后的成活期，加强水肥管理，适时浇灌和培肥土壤，以保证植物的成活和健康生长。

五、有色金属露天矿区生态恢复与重建技术规范研究

在对我国有色金属矿区生态重建技术现状进行调研、总结，并参考《土地复垦技术标准》(试行)(国家土地管理局 1995 年发布)中《采挖废弃土地复垦技术标准》的基础上，编制了《有色金属露天矿区生态恢复与重建技术规范》。本规范对有色金属露天矿区生态恢复与重建过程中设计、表土资源管理、场地整治与土体重构和植物种植等各环节的技术方法和要求作出了规定。

规范条文分八章。

第 1 章：主题内容与适用范围。

第 2 章：引用标准。列出了本规范引用的适用矿区生态恢复与重建有关过程的国家或行业标准。

第 3 章：总则。规定了本规范制定的目的、依据以及矿区生态恢复与重建的原则要求。

第 4 章：生态重建设计。规定了生态重建设计文件编制的依据、主要内容与成果要求。

第 5 章：表土资源管理。规定了采矿剥离作业中对表土资源采集和堆放的要求。

第 6 章：场地整治和土体重构（重建为农地、林地和草地时）。规定了排土场、尾矿场和露天采空区（重建为农地、林地和草地时）场地整治和土体重构的要求，包括污染处置、平台和边坡整治、表层覆盖物料的来源、厚度和污染控制要求。

第 7 章：植物种植。规定了植物种类选择、造林、种草的要求。

第 8 章：露天采空区重建为水域。规定了露天采空区重建为水域的要求，包括水质要求和水体周边的美化要求。

规范条文之后，对有关条文进行了说明。

Summary

1 Status of the damage mining is causing to the eco-environment

1.1 General assessment of the damage to the eco-environment in the mining area

On the whole, the eco-environment problems caused by exploitation of mineral resources in China appear are displayed in the following four aspects:

1) Mining has occupied and damaged lands, including land excavated for open mining, sites for stacking of mullock or earth, sites for stacking gangue, land occupied by mine tailings and land sinking as a result of underground mining.

2) Mining has triggered secondary geological calamities, such as soil erosion, land sliding, mudrock flow, collapse, etc.

3) Mining has polluted the eco-environment, which has in turn led to ecological disorder. Wastewater from the mining and beneficiation processes discharged direct into surface water bodies (rivers or lakes) in the mining areas has caused the waters seriously polluted with organic substances and heavy metals. After a long period of exposure to rains and air, huge stacks of stripped gangues, waste solids and mine tailings containing sulphur compounds in the mining areas would have got oxidated, generating heavy-metal containing acidic water, which seeps into and seriously pollutes surface water and groundwater therein. Draining water from the mine has greatly lowered the groundwater table, resulting in large cones of exhaustion, which in turn disturbs the dynamic balance between surface water and groundwater. The use of wastewater from the mine and water contaminated with acidic leachate from the huge stacks of mine tailings for irrigation has severely polluted farmlands nearby with heavy metals and eventually led to salinization of the soil and degradation in soil fertility and function. Waste gas emitted from mining has seriously polluted the atmosphere in the mining areas, and waste solid and ore tailings have become the major sources of flying dust suspending in the air in the mining areas.

4) Mining has changed the original landscapes and damaged native vegetations, thus leading to land degradation and desertification.

1.2 Zonal characteristics of the ecological disturbance in the mining areas

In terms of zonal characteristics, the ecological damage caused by mining varies in manifestation with the physical geographic zone. In the Qinghai-Tibet Region, Northwest of China, the land occupied and damaged by mining is dominated by grassland, in Northeast China, South China and Southwest China by forestland, and in the middle and lower reaches of the Yangtze River by farmland. In South China and Southwest China, open mining occupies more land than underground mining and in the Qinghai-Tibet Region and the middle and lower reaches of the Yangtze River, the other way round. The impact of mining on landscapes is displayed as wind erosion and desertification of the soil, damaging the structure of the soil layer in the arid and semi-arid regions, as soil erosion and acidic wastewater pollution of valleys in the humid regions, such as South China, Southwest China and the middle and lower reaches of the Yangtze River.

The lands damaged by mining in China are distributed in dots mainly in the eastern and central parts of the country, which is consistent with the status of the exploitation of the mineral resources. Among the minings, coal mining and iron mining often causes larger areas damaged in North China, and nonferrous metal mining does in South China.

1.3 Characteristics of the ecological damage in major mining areas

The ecological damage in major mining areas has the following features. In Shanxi, Central and North Henan and the west edge of the Heilongjiang Sanjiang Plain, coal mining is the major land destroyer and land sinking or subsiding is the major type of land damage as a result of underground mining. On the east edge of the Liaohe Plain and western part of the Liaodong hilly region, open mining of coal and iron ores leads to land loss caused mainly by excavation and occupation. In the northeastern part of Hebei Province exist both open mining and underground mining of iron ores, gold and coal that result in land loss through excavation, occupation and subsidence. In the Gun-Teng Lianghuai Region, which is an important coal belt in East China, the ecological damage is characterized by serious subsidence of the surface ground, resulting from underground mining, thus making it an area that has suffer most from land subsidence in China. In the hilly regions alongside the Yangtze River in Anhui Province mining of copper, iron and sulfur has damaged large tracts of land through occupation, excavation and pollution of farmlands with wastewater and acidic water from the mines. The joint region of Hunan, Jiangxi and Guangdong Provinces is rich in nonferrous metal reserves, of which the open mining needs to remove the overlays and set up dumping sites for mine tailings and mullock, thus covering large tracts of land and pollutes the water systems and soil in the surrounding areas. The mining of gold in the bordering region between Henan and Shaanxi is the major wrong doer. The Qinling Branch Range in that region is the major gold metallogenic belt of the country. Random dumping of the slag has resulted in serious damage to the eco-environment of the region. Moreover, the native approach to beneficiation of the gold ores generates large amounts of Hg-containing wastewater that seriously pollutes nearby waterbodies and farmlands in the down-stream area. In areas in between Yunnan, Guizhou and Sichuan Provinces, the mining and smelting of sulfur has seriously damaged the eco-environment therein and especially the native technology of smelting the mineral has gravely contaminated the soils around.

2 Ecological reconstruction in the mining areas in China

In China the ecological reconstruction in the mining area started in the 1960s. By the 1980s, the work had stepped on to a new stage, an organized one with a certain scale. Currently, the ecological reconstruction in mining areas has been going on dealing with the four major types of ecological damage discussed above, open mining, dumping site for mullock, dumping site for mine tailings (including hills of gangues from coal mining) and ground subsidences resulting from underground mining.

2.1 Ecological reconstruction in goafs left from open mining

Based on the projected targets of ecological reconstruction of the goafs, the following three patterns of reconstruction can be summed up: 1) Agroforestry, that is, to fill up the goaf with soil, which is then leveled for establishing an agroforestry system. Depending on the material used to fill up the goaf, this pattern of reconstruction can be further divided into three models, i.e. filling with stripping, filling with slurry and filling with artificial soil layer; 2) Impoundment, that is to build the goaf into a reservoir for development of tourism and fishery and utilization as a water head source or wastewater treatment pool; 3) Comprehensive utilization, that is, to dig the deep places and fill up the shallow ones; and 4) Restoration of natural vegetation coupled with artificial restoration of vegetation on side slopes. To promote artificially restoration of vegetation can be done in several ways, for instance, supplying seeds, preparing the slopes to create conditions for settlement of the seeds, etc.

2.2 Ecological reconstruction of the dumping site for mullock

Ecological reconstruction of the dumping site for mullock is mainly based on establishment of agroforestry. For that, the following technologies has been used to restore vegetation.

1)Stabilization

In order to stabilize the dumping site, it is essential to set up a sound draining system, set up a biological protection system on its slopes, dump mullock into piles at the late period of the dumping operation and level the dumping site to slopes different in degree in light of the target of the ecological reconstruction.

2) Soil amelioration

To ameliorate the soil at the dumping site, generally two approaches can be adopted. One is to overlay the site with a layer of soil and the other is biological amelioration. The former is to overlay the site with a layer of alien soil, which varies in thickness depending on the nature of the subsoil and the utilization. Normally, the overlay will be 10 – 60 cm thick, which is good enough for agroforestry. The latter includes growing green manure crops, using bio-activators, applying organic manure and neutralize soil pH chemically, all of which are oriented to ameliorating soil. Besides, in the field of management, adoption of reasonable crop rotation and tillage may also help speed up the process of making the soil mellow and fertile.

3) Selection of plant species and matching plantation and configuration techniques

To plant trees and grow grasses, hole plantation for trees and broadcasting for grasses are adopted on dumping sites. The former means to dig holes and then transplant saplings with soil around their roots or fill the holes with alien soil and then transplant saplings. Depending on the time of land preparation, the pattern can be divided into two models, spring-preparation-spring- transplantation and autumn-preparation-spring-transplantation. Besides on the side slopes, the technique of hydraulic broadcasting of seeds and turfing the slopes. On the flat beds and side slopes, vegetation of different composition can be established, such as grass only, grasses-shrubs, and grasses-shrubs-arbor trees.

Based on different conditions of the mullock dumping sites, they can be sorted into three categories for ecological reconstruction. The first category is of dumping sites containing mostly bedrocks and kingles. In this category of dumping sites, which are often located in areas lacking soil sources, the high content of bedrocks and kingles goes against survival of plants. It is advisable to make use of wastes, such as debris, mine tailings, slag, flyash, sludge, garbage, etc. as filling and then plant stress-resistant trees. The second category of dumping sites has little surface soil but much weatherable rock. These sites are often located in hilly regions with little surface soil, so it is hard to gather enough soil to overlay the site. But the rocks there are liable to weather. It is, therefore, adequate to level the ground somewhat and directly plant stress-resistant and fast-growing trees and grasses. The third category of dumping sites is rich in surface soil, which can be used to overlay the site with. And then agroforestry can be established thereupon.

2.3 Ecological reconstruction of the dumping site for mine tailing

Ecological reconstruction of the dumping site for mine tailing includes amelioration of the soil on the dumping site, screening and planting of plants and selection of configuration models.

As mine tailings are often very simple in mechanical composition, poor in moisture and nutrient retention, either too high or too low in pH, and excess in content of heavy metals and salts, which are unfavorable for establishment and growth of plants. It is, therefore, essential to take positive measures to ameliorate the soil first, such as neutralizing acidic mine tailings with lime, readjusting alkaline ones with gypsum or calcium chloride, and overlaying those containing toxic heavy metals with an insolating layer and soil.

In selecting pioneer plants, it is advisable to choose native tree species that have strong vitality and tolerance to infertility of the soil and introduce in properly some species from elsewhere.
On these sites, seeds can be sown directly or saplings transplanted in dug holes. And the pattern of the vegetation to be restored can be of forestry-pasture, orchard-pasture or agroforestry.

Depending on conditions of the mine tailing dumping sites and economic conditions of the mines, the ecological reconstruction of the dumping sites could be grouped into two types, with overlay and without overlay. The latter is often adopted in areas lacking soil resources. It saves the work of overlaying the mine tailings, but limits the range of plant species for choice and calls for intensive field management. The former is preferable in areas rich in soil resources. The overlay is generally 50 cm or more thick.

In South China, mines are generally in areas lacking soil resources. It is a common practice to stack the stripped surface soil aside and later to overlay the dried mine tailings with the soil.

2.4 Ecological reconstruction of gangue mounts

Gangue mounts are huge piles of gangues, also a kind of mine tailing, thrown out during mining and beneficiating coal. Ecological reconstruction of the gangue mounts can also be accomplished by artificial afforestation. Currently the following technologies are available for adoption.

1) Technology for leveling gangue mounts and erosion control. As gangue mounts are coarse in mechanical composition and poor in water holding capacity, it is advisable to prepare the mounts into holes or terrace fields in fall and plant trees in spring.

2) Technology for amending acidic gangue mounts. To neutralize the acidity or strong acidity resulting from spontaneous combustion of the gangue, generally CaO or $CaCO_3$ is used and broadcast evenly over the gangue mounts in crushed form at a rate depending on pH value of the gangue, purity of the neutralizer used and thickness of the gangue layer.

3) Technology of overlaying. To solve the problems of nutrient deficiency of the gangue mounts and high temperature of the surface layer, the mounts are overlaid with a layer of soil 5 – 10 cm thick or 50 cm thick or nothing depending on weathering degree of the surface of the mounts before they are planted.

4) Technology of afforestation on gangue mounts. For afforestation, different plantation patterns can be adopted in light of the species of plants chosen. For deciduous arbors and shrubs, a small amount of earth is needed in each pit for transplantation, for evergreen trees, they are transplanted with earth around their roots, for flowers and grasses, their seedlings are transplanted with their roots dipping into slop first and their seeds are sown in mixture with fine earth, and for some deciduous arbors and shrubs, such as loblolly, acacia, etc. they are cut short or heavily pruned before transplantation.

2.5 Ecological reconstruction of subsidence areas

The ecological reconstruction of subsidence areas can be designed for a range of targets, such as agriculture, building, waters (fish ponds, parks, reservoirs) etc., depending on types of the subsidence. Currently ecological reconstruction of subsidence areas tends to be oriented for comprehensive utilization. In light of types of the damage of subsidence to the eco-environment, the ecological reconstruction of subsidence areas can be sorted into the following patterns:

1) Agriculture-based comprehensive exploitation of steady-going subsidence areas without waterlogging. Fill up the subsidence area with gangue flyash or other materials (silt from rivers or lakes), level the filling and overlay it with soil. Then the area is ready for cultivation of agriculture and afforestation. Or Prepare the side slopes of the subsidence area direct into terrace fields or slope fields instead of filling it up, and then set up an farmland eco-system of farming combined with orchards so as to conserve water and soil.

2) Construction-development-based utilization of steady-going subsidence areas without waterlogging.

3) Agriculture-forestry-fishery-based comprehensive ecological reconstruction on steady-going seasonal waterlogged subsidence areas. Make the hollow area hollower for raising fish, cultivating lotus or conserving water for irrigation, and place the earth excavated from the hallow part over on the part that is less subsided and prepare it into paddy fields or upland fields for growing crops.

4) Agriculture-forestry-fishery-based comprehensive ecological reconstruction on steady-going permanent shallowly waterlogged subsidence areas. Build the area into a fish pond and set up agriculture and forestry in some parts by making the hallow part hollower and the shallow part filled up.

5) Aquiculture-based comprehensive exploitation of the steady-going permanent deeply waterlogged subsidence areas. Besides, developing fish rearing, build up aquatic parks, water purification plants, wastewater treatment plants or reservoirs by making use of the deep water area if it is large enough.

3 Ecological rehabilitation and reconstruction of mines in other countries

Ecological reconstruction started the earliest in the US and Germany. In 1920, the US passed an act on "Mine Leasing", which stipulated specifically conservation of the land resources and natural environment. And in the 1920s a campaign of afforestation was launched on deserted coal mines in Germany. In the 1950s some countries began systematic afforestation of the areas planned for ecological reconstruction. In the 1960s most industrially-developed countries sped up their paces in formulating laws or rules for ecological reconstruction and intensified promotion of ecological reconstruction projects, which show that they were conscientiously entering into the age of scientific ecological reconstruction. In the 1970s, ecological reconstruction had developed into a systems engineering that technically integrates various disciplines, such as mining,