doi: 10.12029/gc2019Z103

论文引用格式：钟婉婷，李玉彬，李玉昌，刘超强，陈晓深. 2019. 西藏多不杂斑岩铜矿资源储量数据集 [J]. 中国地质，46(S1):18−31.

数据集引用格式：钟婉婷; 李玉彬; 李玉昌; 刘超强; 陈晓深. 西藏多不杂斑岩铜矿资源储量数据集 (V1). 成都理工大学;中国地质调查局成都地质调查中心;西藏自治区地质矿产勘查开发局第五地质大队 [创建机构]，2005. 全国地质资料馆 [传播机构], 2019-06-30. 10.23650/data.C.2019.P2; http://dcc.ngac.org.cn/geologicalData/rest/geologicalData/geologicalDataDetail/91226d55f54252af86c6c381b0f6dcb3

收稿日期：2018-08-10
改回日期：2019-04-23

基金项目：中国地质调查局地质调查项目“中国矿产地质与成矿规律综合集成和服务（矿产地质志）”（DD20160346、DD20190379）资助。

西藏多不杂斑岩铜矿资源储量数据集

钟婉婷[1,2]　李玉彬[1,3*]　李玉昌[3]　刘超强[3]　陈晓深[3]

(1. 成都理工大学，四川 成都 610059；2. 中国地质调查局成都地质调查中心，四川 成都 610081；3. 西藏自治区地质矿产勘查开发局第五地质大队，青海 格尔木 816000)

摘要：西藏多不杂铜矿是班公湖−怒江成矿带近年来发现的第一个大型斑岩铜矿床。该矿床位于班公湖−怒江缝合带北缘多不杂构造岩浆弧中，形成于早白垩世班公湖−怒江多岛弧−盆系演化时期，成矿年龄为 120 Ma，成矿与侵位于早白垩统美日切错组地层中的石英闪长玢岩、花岗闪长斑岩有关。目前已探明铜、金资源量分别为 230 万吨，92 吨，平均品位分别为 0.51%、0.2 g/t，已达超大型矿床规模，是国家矿产资源战略储备基地。本数据集是在 2005—2010 年对该矿区矿产勘查所取得的宝贵数据基础上，开展的数据库建设的成果，采用 10 个数据表，重点汇集了多不杂铜矿单工程工业矿体和低品位矿体的品位数据及其计算结果，并对与储量计算有关的所有细节性数据做了系统性的归并整理。

关键词：西藏；多不杂铜矿；品位；资源储量；数据集
数据服务系统网址：http://dcc.cgs.gov.cn

1　引言

多不杂矿床是 1997 年西藏地质五队开展砂金调查评价过程中发现的。随着地质调查项目经费连续投入，在其周围新发现一批矿产地，如波龙、拿若、拿顿、地堡那木岗、铁格隆南（荣那）、色那、尕尔勤、赛角、拿厅等铜（金）多金属矿床（李玉彬等，2012a，b；方向等，2013；杨欢欢等，2014；李光明等，2015；李兴奎等，2015；唐菊兴等，2016；高轲等，2011；乔东海等，2017；王勤等，2018），从而形成多龙铜金矿集区。其中，多不杂、波龙、拿若、铁格隆南（荣南）四个矿床已达到超大型规模，尤以多不杂铜矿品位高、埋藏浅。目前，多龙矿集区是班公湖—怒江成矿带勘探程度最高的矿集区，这一矿集区的发现及研究，为班公湖—怒江成矿带西段铜多金属成矿带的深入研究以及藏西北有色金属储备基地的建设，提供了丰富的基础资料和数据支撑。

西藏班公湖—怒江成矿带西段铜多金属调查项目近年来取得重大找矿突破。工作主

第一作者简介：钟婉婷，女，1982 年生，工程师，主要从事成矿规律与成矿预测研究；E-mail：67027693@qq.com。
通讯作者简介：李玉彬，男，1982 年生，高级工程师，主要从事矿床勘查评价；E-mail：liyb73@163.com。

体区域多龙矿集区，以多不杂—波龙矿区为中心，东起昂龙，西至地堡那木岗，呈近北东向展布，地理坐标：东经 83°15′～83°45′，北纬 32°45′～32°54′，东西长约 45 km，南北宽约 20 km，面积约为 900 km^2（图 1）。

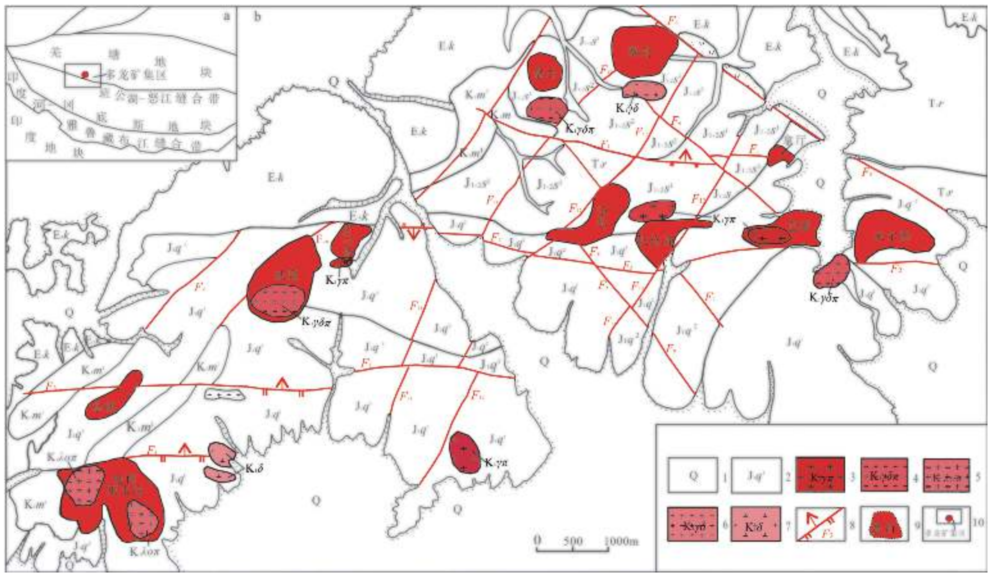

图 1　多龙矿集区地质简图（据李玉彬等，2012）

图 a：多龙矿集区区域位置图；图 b：多龙矿集区地质简图。1—第四系；2—地层代号；3—早白垩世花岗斑岩；4—早白垩世花岗闪长斑岩；5—早白垩世石英斑岩；6—早白垩世花岗闪长岩；7—早白垩世闪长岩；8—正断层；9—矿区及名称；10—多龙矿集区区域位置

西藏多不杂矿区资源储量数据集元数据简表见表 1。

表 1　数据库（集）元数据简表

条目	描述
数据库（集）名称	西藏多不杂斑岩铜矿资源储量数据集
数据库（集）作者	钟婉婷 成都理工大学，中国地质调查局成都地质调查中心 李玉彬 成都理工大学，西藏自治区地质矿产勘查开发局第五地质大队 李玉昌 西藏自治区地质矿产勘查开发局第五地质大队 刘超强 西藏自治区地质矿产勘查开发局第五地质大队 陈晓深 西藏自治区地质矿产勘查开发局第五地质大队
数据时间范围	2005—2010年
地理区域	西藏改则县多不杂矿区
数据格式	*.docx
数据量	9.54 Mb
数据服务系统网址	http://dcc.cgs.gov.cn
基金项目	中国地质调查局地质调查项目“中国矿产地质与成矿规律综合集成和服务（矿产地质志）”（编号：DD20160346、DD20190379）资助
语种	中文
数据库（集）组成	西藏多不杂矿区资源储量数据集为Word文档型数据，包含10个表格，分别为“单工程基本情况表”、“单工程工业矿、低品位矿平均品位计算表”、“矿体连接面积信息表”、“块段相邻勘探线剖面面积计算表”、“块段加权平均品位计算表”、“块段资源储量估算表”、“矿体资源量估算汇总表”、“平均体重计算结果表”、“矿体品位变化系数计算表”、“矿体厚度变化系数计算表”等内容。

2 矿区地质特征

多不杂斑岩铜矿区面积约为 8.66 km^2，该矿床属第 I 勘探类型，其普查工作基本网度采用（200～400）×（100～200）m，根据地表及深部工程（浅井、槽探、钻探）圈定了一个斑岩型铜矿体。矿体出露于 39～24 号勘探线之间，近东西向展布、向南陡倾，为巨厚板状体，倾角 40°～60°，控制矿体长度 1 600 米，厚度 200～500 米，宽度 200～600 米。

矿体主要产于花岗闪长斑岩体上部的钾化带、绢英岩化带，以及花岗闪长斑岩体边部的青磐岩化变长石石英砂岩中。斑岩体中铜矿化以浸染状、细脉状黄铜矿化为主，岩体与围岩的内外接触带部位，以脉状、网脉状黄铜矿化为主，铜品位明显增高；外侧青磐岩化变长石石英砂岩中以脉状、细脉状、浸染状黄铜矿化为主，铜品位逐渐降低。矿床平均品位为 Cu 0.51%、Au 0.2 g/t。

矿体 Cu 平均品位在东西延展方向上变化较大，23 线、07 线、00 线、08 线、16 线品位较高，为 0.5%～0.73%（图 2）；而 31 线、15 线、24 线品位较低，为 0.27%～0.35%，总体具有中间高，东西两侧低的特征（表 2）；矿体在垂向上 Cu 品位变化较大，总体表现为斑岩及接触带附近品位较高，变长石石英砂岩中品位相对较低，铜、金呈明显的正相关关系（图 3）。其中 23 线钻孔施工深度为 601.41 m，未穿透矿体，控制矿体延深达 565.31 m，而相距仅 200 米的 31 线钻孔施工深度为 356.41 m，仅在近地表控制矿体延深 22 m；16 线、24 线也存在类似现象，说明矿体形态相对复杂。

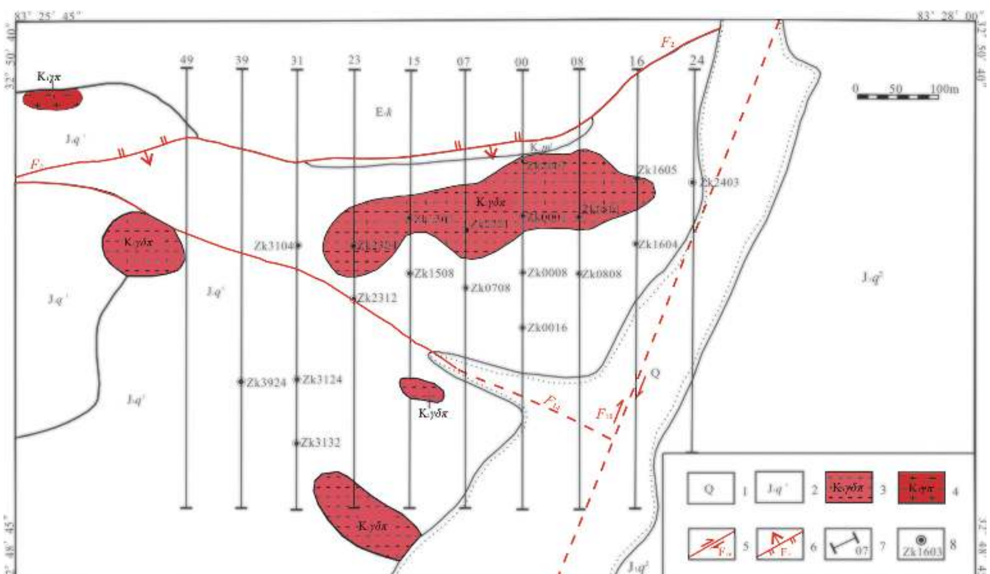

图 2 多不杂矿区 0#勘探线剖面图

1—地层代号；2—早白垩世花岗闪长斑岩；3—平移断层；4—钻孔及编号；5—工业矿体；6—低品位矿体

多不杂铜矿顶部矿体遭受氧化作用，局部地段具次生富集带，矿体以原生矿为主。矿体主要分布于斑岩体中及内外接触带、近岩体蚀变围岩中，主要表现为岩体全岩矿化，以细粒、微细粒、细脉浸染状矿石为主。在内外接触带附近，矿化最佳，以脉状、网脉状矿石为主；在近岩体蚀变围岩中以浸染状矿石为主，向外侧品位逐渐下降。多不杂铜矿体以原生矿为主，主要铜矿物为黄铜矿，地表见孔雀石、蓝铜矿及辉铜矿。黄铜矿呈黄铜色，它形细粒状、浸染状、细脉状集合体赋存于花岗闪长斑岩及砂岩中；孔雀

石、蓝铜矿呈薄膜状、纤维状集合体、粉尘状、团块状集合体、斑点状赋存在花岗闪长斑岩中或碎裂砂岩中，局部地段见少量辉铜矿。

表 2　钻探工程见矿特征统计表

勘探线	31线	23线	15线		07线		00线		08线		16线		24线	备注
工程编号	3104	2304	1501	1508	0701	0708	0001	0008	0801	0808	1605	1604	2405	
单工程铜品位(%)	0.27	0.73	0.38	0.29	0.86	0.30	1.01	0.36	0.69	0.31	0.77	0.26	0.35	
单工程金品位(g/t)	–	0.30	–	–	0.41	0.17	0.46	0.13	0.43		0.16		0.12	2304、1508、0808、1604、1605均未穿透矿体
单工程矿体厚度(m)	22	565.31	88.48	380.4	283.06	226.74	222.32	393.04	196	401.61	379.40	395	92.56	
线平均铜品位(%)	0.27	0.73	0.34		0.63		0.68		0.50		0.52		0.35	
线平均工程金品位(g/t)	–	0.30	–		0.29		0.30		–		–		0.12	
各勘探线矿体厚度(m)	22	565.31	235.44		255.9		307.78		298.80		387.2		92.56	

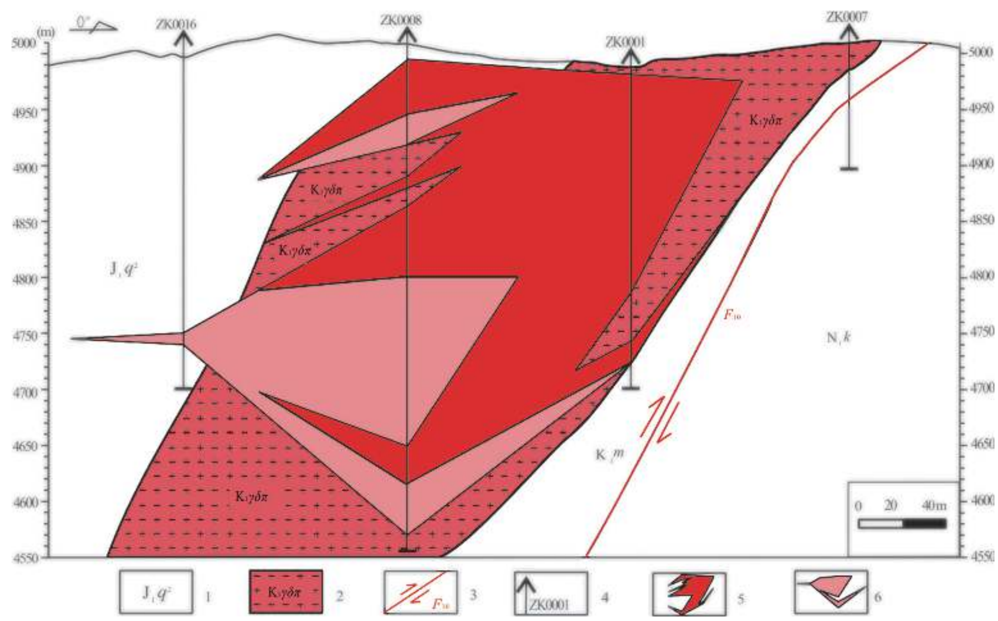

图 3　多不杂矿区勘探线布置图（据李玉彬等，2012a）

1—第四系；2—地层代号；3—早白垩世花岗闪长斑岩；4—早白垩世花岗斑岩；5—平移断层；6—正断层及编号；7—勘探线及编号；8—钻孔及编号

3　数据采集和处理方法

3.1　样品采集

钻孔岩心取样：在岩心库，岩心被岩心切割机一分为二。从开孔至终孔连续取样。样长原则上为 2 m，视具体情况（如跨层等）增加或缩减取样长度，但基本控制在 2±0.5 m 以内，共采集岩、矿芯样 11 929 件。

小体重取样：样品是在钻孔的岩心副样中采取，按不同的矿石类型分别采取，野外

共采取小体重样 65 件，封蜡保存后送实验室测试。

3.2 测试方法

样品委托测试单位为西藏地质矿产勘查开发局中心实验室第五分室承担，其资质为国家实验分析甲级。外检样品送至原国土资源部成都矿产资源监督检测中心和原国土资源部沈阳矿产资源监督检测中心进行分析，其资质均为国家实验分析甲级。体重样采用常规水浸比重测量分析方法，化验分析采用常规测试法。

3.3 资源储量估算方法

3.3.1 采用的工业指标

多不杂矿区地处藏北高原腹地，进行资源量估算的主要矿体产状陡、厚度巨大、适宜露天开采，矿体露头物理风化明显，矿石自然类型大多为硫化矿石，因此根据《铜、铅、锌、银、镍、钼矿地质勘查规范》（DZ/T0214-2002）、《固体矿产推断的内蕴经济资源量和经工程验证的预测资源量估算技术要求》（DD 2002-1）等规范、规定，结合该矿区主矿体的矿石特征以及未来矿山的采矿方式，最终确定矿区的工业指标为：

边界品位（Cu）0.2%；

最低工业品位（Cu）0.4%；

最小可采厚度≥4 m；

夹石剔除厚度≥8 m；

伴生有用组分平均品位 Au（g/t）：0.1；Ag（g/t）：1.0。

3.3.2 资源储量估算方法的选择

按照相关规范要求，矿床勘查类型的划分，应依据矿体规模、主矿体形态及内部结构、矿床构造影响程度、主矿体厚度稳定程度和有用组分分布均匀程度等五个主要地质因素来确定。为了量化这些因素的影响大小，引入类型系数的概念，对每个影响因素都赋予一定的数值，依据五个地质因素类型系数之和就可以合理确定其勘查类型。根据规范要求，五个地质因素类型系数之和介于 2.5~3.0 时，其对应矿床为第 I 勘查类型。多不杂铜矿的五个地质因素类型系数之和为 2.8，所以确定该矿床为第 I 勘查类型。

3.3.3 资源量估算主要参数的确定

采用垂直平行断面法估算资源量，所选用的参数包括：品位、厚度、面积、体积、体重、矿石量、金属量。计算精度：品位、厚度、体重精确到小数点后二位数；面积、体积、矿石量、金属量取整数，尾数采用四舍五入法进位。

1）品位

（1）单工程矿体平均品位

矿区圈入矿体的各样品长度变化不大，单工程矿体平均品位采用加权平均法计算，将圈入矿体的各样品的品位与样品长度加权平均求得。

（2）剖面平均品位

用剖面上各相邻矿体的单工程厚度（视厚度）加权平均求得。

（3）块段平均品位

采用块段剖面平均品位与剖面面积加权平均求得。

（4）矿体平均品位

采用矿体的金属量除以矿石量求得。

（5）矿床平均品位

采用矿区的金属量除以矿石量求得。

（6）特高品位的处理

按规范要求，“品位值高于矿体（床）平均品位 6 ~ 8 倍的样品称为特高品位”，处理方法为“用计算出的块段或单工程平均品位，代替该样品品位参与矿段或单工程平均品位的正常计算”。多不杂矿区特高品位确定为 0.513%×8=4.12%，除 ZK0001 钻孔中铜分析结果大于该指标外，其它钻孔均未见高于此品位。根据地质规律和 ZK0001 见矿品位高且具连续出现的特点，作为富矿段处理，故多不杂矿区无特高品位。

2）面积

剖面面积（S）采用计算机软件直接求取并编号，按照由西至东的勘探线顺序，在资源量估算剖面图上按照从左到右、由上到下的原则，将工业矿体、低品位矿体分为不同的块段截面并依次编号。

3）体积

平行剖面块段体积的计算

相邻剖面间的体积计算采用如下公式：

$$V = \frac{1}{2}(S_1 + S_2) \times L\left(\text{面积差} < 40\%\right) \tag{1}$$

$$V = \frac{1}{3}\left(S_1 + S_2 + \sqrt{S_1 \times S_2}\right) \times L\left(\text{面积差} > 40\%\right) \tag{2}$$

式中：V 块段体积；S_1、S_2 分别为同一块段相邻剖面的剖面面积，L 两条相邻剖面的垂直距离。

边界剖面外推的体积计算采用如下公式：$V = \frac{1}{2}S \times L$（剖面呈楔形尖灭）

$V = \frac{1}{3}S \times L$（剖面呈锥形尖灭）

式中：S 剖面面积；L 外推点到相邻剖面的垂直距离。

4）体重

矿石体重采用矿区矿石小体重样测定数据的算术平均值，多不杂矿区矿石平均体重为 2.58 t/m^3。

5）矿石量

采用体积与体重平均值乘积求得，采用公式：$q = s \times t \times d$

式中：q–矿体矿石资源量（t）；s–矿体面积（m^2）

t–矿体平均厚度（m）；d–矿体体重（t/m^3）。

6）金属量

采用矿石量与平均品位乘积求得，采用公式：$p = q \times c$

p – 矿体金属资源量（t）；c – 铜矿体平均品位（%）。

3.3.4 资源量类别和块段划分原则

根据《固体矿产普查暂行规定》（DD 2000-02）和《固体矿产预查暂行规定》（DD 2000-01）,并参考中地调函［2002］234.44 号文（固体矿产推断的内蕴经济资源量和经工程验证的预测资源量估算技术要求）（DD 2002-1）来确定推断的内蕴经济资源量（333）和预测的内蕴经济资源量（334）。

1）资源量类别

多不杂矿区工程布设按原国土资源部地质矿产行业标准《地质勘查规范》〔2003〕要求进行。按 100×100 m 的工程网度通过浅井、探槽进行了地表揭露，圈定了矿化范围，在此基础上按（200～400）×（200～400）m 的网度，由 0 号、7 号、8 号、15 号、16 号、23 号、24 号、31 号、39 号勘探线共 19 个钻孔进行稀疏控制，18 个钻孔均见铜矿体。

满足工程网度 400×400 m 的工程控制区域资源量类型为 333，按基本工程网度 400×400 m 无限外推的资源量类型为 334：尖推 200 米。

2）块段划分

块段划分原则以相邻勘探线剖面之间同一矿体同一资源量类型按工程点连接成一个自然块段。以资源量类别为依据，在资源量估算平面图上，按照矿体类别由左到右、自上而下分别依次编号。多不杂铜矿分为工业矿体与低品位矿体两个类别分别估算资源量，其中工业矿体划分 26 个自然块段；低品位矿体划分 28 个自然块段。

4　数据样本描述

“单工程基本情况表”包括如下内容（表 3）：矿体编号、勘探线编号、工程编号、样品编号、采样位置、样品长度、样品分析结果、样长与品位之积、样长与品位乘积之和、矿体厚度、平均品位、备注。

表 3　“单工程基本情况表”数据表内容

序号	字段名称	量纲	数据类型	实例
1	矿体编号	–	字符型	I
2	勘探线编号	–	字符型	39
3	工程编号	–	字符型	ZK3924
4	样品编号	–	字符型	H48
5	采样位置	m	字符型	–
	自	m	浮点型	93.12
	至	–	浮点型	95.12
6	样品长度	m	浮点型	2
7	样品分析结果	–	浮点型	–
	Cu	%	浮点型	0.36
	Au	g/t	浮点型	0.1
8	样长与品位之积	–	浮点型	–
	Cu	–	浮点型	0.72
	Au	–	浮点型	0.19
9	样长与品位乘积之和	–	浮点型	–
	Cu	–	浮点型	7.84
	Au	–	浮点型	2.35
10	矿体厚度	m	浮点型	14

续表 3

序号	字段名称	量纲	数据类型	实例
11	平均品位	–	浮点型	–
	Cu	%	浮点型	0.56
	Au	g/t	浮点型	0.17
12	备注	–	字符型	–

“单工程工业矿、低品位矿平均品位计算表”包括如下内容（表 4）：工程编号、矿体类别、总矿体、工业矿体、低品位矿体、样品编号、取样位置、矿层见矿厚度、矿层品位与见矿厚度乘积之和、矿层平均品位、单工程见矿厚度、单工程见矿厚度与品位乘积之和、单工程平均品位。

表 4　“单工程工业矿、低品位矿平均品位计算表”数据表内容

序号	字段名称	量纲	数据类型	实例
1	工程编号	–	字符型	ZK3924
2	矿体类别	–	字符型	–
	总矿体	–	浮点型	38.6
	工业矿体	–	浮点型	22
	低品位矿体	–	浮点型	16.6
3	样品编号	–	字符型	–
	自	m	浮点型	H48
	至	m	浮点型	H54
4	取样位置	m	浮点型	–
	自	m	浮点型	93.12
	至	m	浮点型	107.12
5	矿层见矿厚度	m	浮点型	14
6	矿层品位与见矿厚度乘积之和		浮点型	–
	∑Cu*H		浮点型	7.84
	∑Au*H		浮点型	2.53
7	矿层平均品位		浮点型	–
	Cu	%	浮点型	0.56
	Au	g/t	浮点型	0.17
8	单工程见矿厚度	m	浮点型	–
	总矿体	m	浮点型	38.6
	工业矿体	m	浮点型	22
	低品位矿	m	浮点型	16.6
9	单工程见矿厚度与品位乘积之和	–	浮点型	–
	总矿体(Cu)	%	浮点型	15.88
	工业矿体(Cu)	%	浮点型	12.16
	低品位矿(Cu)	%	浮点型	3.72

续表 4

序号	字段名称	量纲	数据类型	实例
10	总矿体(Au)	g/t	浮点型	10.45
	工业矿体(Au)	g/t	浮点型	8.53
	低品位矿(Au)	g/t	浮点型	1.91
11	单工程平均品位	–	浮点型	–
	总矿体(Cu)	%	浮点型	0.41
	工业矿体(Cu)	%	浮点型	0.55
	低品位矿(Cu)	%	浮点型	0.22
	总矿体(Au)	g/t	浮点型	0.27
	工业矿体(Au)	g/t	浮点型	0.36
	低品位矿(Au)	g/t	浮点型	0.12
12	备注	–	字符型	–

“矿体连接面积信息表”包括如下内容（表 5）：勘探线编号、矿体编号、品级、面积编号、毛面积、净面积、内套面积、平均品位。

表 5 “矿体连接面积信息表”数据表内容

序号	字段名称	量纲	数据类型	实例
1	勘探线编号	–	字符型	0
2	矿体编号	–	字符型	DBZM1
3	品级	–	字符型	工业矿
4	面积编号	–	字符型	0_13
5	毛面积	–	–	39 676.7
6	净面积	–	–	35 696.24
7	内套面积	–	–	3 980.46
8	平均品位	–	–	–
	Cu	%	–	0.85
	Au	g/t	–	0.32

“块段相邻勘探线剖面面积计算表”包括如下内容（表 6）：矿体号、块段号、构成块段工程、块段空间形态、块段剖面面积、剖面间距。

表 6 “块段相邻勘探线剖面面积计算表”数据表内容

序号	字段名称	量纲	数据类型	实例
1	矿体号	–	字符型	DBZM1
2	块段号	–	字符型	DBZ08
3	构成块段工程	–	字符型	–
	构成面积S1工程	–	字符型	Zk1501
		–	字符型	Zk1508
	构成面积S2工程	–	字符型	Zk0701
		–	字符型	Zk0708

续表 6

序号	字段名称	量纲	数据类型	实例
4	块段空间形态	–	字符型	截锥
5	块段剖面面积	–	字符型	–
	面积号1	–	字符型	15_4,15_9,15_12,15_13
	S_1	m^2	浮点型	3 544.63
	面积号2	–	字符型	7_43
	S_2	m^2	浮点型	36 097.01
6	剖面间距	m	浮点型	200

“块段加权平均品位计算表”包括如下内容（表 7）：矿体号、块段号、储量类型、块段空间形态、块段剖面面积、Cu 平均品位、S_1 平均品位（Cu%）、S_2 平均品位（Cu%）、块段平均品位（Cu%）、Au 平均品位、S_1 平均品位（Au g/t）、S_2 平均品位（Au g/t）、块段平均品位（Au g/t）。

表 7 “块段加权平均品位计算表”数据表内容

序号	字段名称	量纲	数据类型	实例
1	矿体号	–	字符型	DBZM1
2	块段号	–	字符型	DBZ06
3	储量类型	–	字符型	334
4	块段空间形态	–	字符型	截锥
5	块段剖面面积	m^2	浮点型	–
	S_1	m^2	浮点型	31 788.63
	S2	m^2	浮点型	4 489.77
6	Cu平均品位	%	浮点型	–
	S_1平均品位	%	浮点型	0.56
	S_2平均品位	%	浮点型	0.42
	块段平均品位	%	浮点型	0.55
7	Au平均品位	g/t	浮点型	–
	S_1平均品位	g/t	浮点型	0.27
	S_2平均品位	g/t	浮点型	0.08
	块段平均品位	g/t	浮点型	0.25

“块段资源储量估算表”包括如下内容（表 8）：矿体号、储量类型、块段号、块段剖面面积、块段空间形态、剖面间距、块段总体积、体重、矿石量、平均品位（Cu）、金属量（Cu）、平均品位（Au）、金属量（Au）。

表 8 “块段资源储量估算表”数据表内容

序号	字段名称	量纲	数据类型	实例
1	矿体号	–	字符型	DBZM1
2	储量类型	–	字符型	333
3	块段号	–	字符型	DBZ10

续表 8

序号	字段名称	量纲	数据类型	实例
4	块段剖面面积	–	字符型	–
	S_1	m^2	浮点型	86 017.58
	S_2	m^2	浮点型	3 544.63
5	块段空间形态	–	字符型	截锥
6	剖面间距	m	浮点型	200
7	块段总体积	m^3	浮点型	7 134 908.22
8	体重	t/m^3	浮点型	2.58
9	矿石量	t	浮点型	18 408 063.2
10	Cu金属量	–	浮点型	–
	平均品位	%	浮点型	0.71
	金属量	t	浮点型	130 697.25
11	Au金属量	–	浮点型	–
	平均品位	g/t	浮点型	0.28
	金属量	kg	浮点型	5 154.26

“矿体资源量估算汇总表”包括如下内容（表 9）：矿体号、品级、储量类型、矿体体积、矿石量、平均品位（Cu）、资源量（Cu）、平均品位（Au）、资源量（Au）、备注。

表 9 “矿体资源量估算汇总表”数据表内容

序号	字段名称	量纲	数据类型	实例
1	矿体号	–	字符型	DBZM1
2	品级	–	字符型	工业矿体
3	储量类型	–	字符型	333
4	矿体体积	m^3	浮点型	57 190 409.3
5	矿石量	t	浮点型	147 551 256
6	Cu平均品位	%	浮点型	0.74
7	Cu资源量	t	浮点型	1 096 826.83
8	Au平均品位	g/t	浮点型	0.28
9	Au资源量	kg	浮点型	40 609.16
10	备注		字符型	–

“平均体重计算结果表”包括如下内容（表 10）：野外编号、分析结果（矿石重、封蜡重、浮重、矿石密度）、采样位置、岩性、化学分析结果（*w*(Cu)，*w*(Au)）、平均体重。

表 10 “平均体重计算结果表”数据表内容

序号	字段名称	量纲	数据类型	实例
1	野外编号	–	字符型	BT1
2	分析结果	–	浮点型	–

续表 10

序号	字段名称	量纲	数据类型	实例
3	矿石重	g	浮点型	111
	封蜡重(g)	g	浮点型	113
	浮重	g	浮点型	66.5
	矿石密度	g/cm^3	浮点型	2.51
4	采样位置	–	浮点型	ZK0701-27 m
5	岩性	–	字符型	花岗闪长斑岩
6	化学分析结果	–	浮点型	–
	w(Cu)	%	浮点型	1.45
	w(Au)	g/t	浮点型	0.43
7	平均体重	g/cm^3	浮点型	2.58

“矿体品位变化系数计算表”包括如下内容（表 11）：工程编号、单工程平均品位、工程个数、矿体单工程平均品位之和、矿体单工程算术平均品位、单工程平均品位与矿体单工程算数平均品位之差、差平方、差平方之和、均方差、变化系数、备注。

表 11　“矿体品位变化系数计算表”数据表内容

序号	字段名称	量纲	数据类型	实例
1	工程编号	–	字符型	ZK3924
2	单工程平均品位	–	浮点型	–
	Cu(Au)	%	浮点型	0.41
3	工程个数	n	浮点型	17
4	矿体单工程平均品位之和	%	浮点型	8.09
5	矿体单工程算术平均品位	%	浮点型	0.48
6	单工程平均品位与矿体单工程算术平均品位之差	%	浮点型	−0.07
7	差平方	%	浮点型	0.004 7
8	差平方之和	%	浮点型	0.937 7
9	均方差	%	浮点型	0.242 1
10	变化系数	%	浮点型	50.85%
11	备注	–	字符型	n<25时,采用n-1

“矿体厚度变化系数计算表”包括如下内容（表 12）：工程编号、单工程见矿厚度、工程个数、单工程见矿厚度之和、单工程算术平均见矿厚度、单工程见矿厚度与单工程算术平均见矿厚度之差、差平方、差平方之和、均方差、变化系数、备注。

表 12　“矿体厚度变化系数计算表”数据表内容

序号	字段名称	量纲	数据类型	实例
1	工程编号	–	字符型	ZK3924
2	单工程见矿厚度	m	浮点型	38.6
3	工程个数	n	浮点型	17
4	单工程见矿厚度之和	m	浮点型	4 117.55

续表 12

序号	字段名称	量纲	数据类型	实例
5	单工程算术平均见矿厚度	m	浮点型	242.21
6	单工程见矿厚度与单工程算术平均见矿厚度之差	m	浮点型	−203.61
7	差平方	m	浮点型	41 457.03
8	差平方之和	m	浮点型	429 146.69
9	均方差	m	浮点型	163.77
10	变化系数	%	浮点型	67.62%
11	备注	–	字符型	n<25时，采用n−1

5 数据质量控制和评估

西藏多不杂矿区资源储量数据集来自“国土资源大调查”（2005—2007 年）和“青藏专项”（2008—2010 年）计划中的“战略性矿产资源调查评价”项目，是在前期的“西藏改则县多不杂铜矿普查”项目基础上获得的矿产勘查宝贵数据。该矿区资源储量报告于 2012 年提交。数据质量来源真实可靠；资源储量计算是依据该矿床类型及矿体实际情况采用国内外通用计算方法来实现的，计算方法选择可行、得当，后期随着该矿区勘查工作持续推进，会对相关数据进行维护、校准、更新。本数据集的数据质量具有实用性、准确性、连续性、可推广性等特点。

6 结论

西藏多不杂矿区资源储量数据集可以反映近年来在班公湖−怒江成矿带又一重大找矿成果。截止项目结题，多不杂获得 333 + 334 铜金属资源量 230 余万吨，伴生金金属资源总量 92 余吨，矿体平均品位铜 0.51%，伴生金平均品位 0.20 g/t。该矿床进行资源储量的调查与评估，可以对周边矿床的资源储量评估做一参考，同时对班公湖−怒江成矿带同类型矿床的分带分型情况具有参考意义。

致谢：诚挚感谢西藏地质五队张天平高级工程师、范安徽工程师对本文的指导，感谢张新元编辑对本文给予的建设性、指导性修改意见！

参考文献

高轲, 唐菊兴, 宋扬, 刘治博, 方向, 杨欢欢, 王勤, 林彬, 王艺云. 2011. 西藏拿若隐爆角砾岩中岩浆岩成因: 来自锆石 Hf 同位素证据 [J]. 地球与勘探, 53(2): 207−216.

李光明, 张夏楠, 秦克章, 孙兴国, 赵俊兴, 印贤波, 李金祥, 袁华山. 2015. 羌塘南缘多龙矿集区荣那斑岩−高硫型浅成低温热液 Cu-(Au) 套合成矿: 综合地质、热液蚀变及金属矿物组合证据 [J]. 岩石学报, 31(8): 2307−2324.

李兴奎, 李才, 孙振明, 吴浩. 2015. 西藏赛角铜金矿闪长岩 LA-ICP-MS 锆石 U-Pb 年龄、Hf 同位素和地球化学特征及成矿意义 [J]. 地质通报, 34(5): 908−918.

李玉彬, 多吉, 钟婉婷, 李玉昌, 强巴旺堆, 陈红旗, 刘鸿飞, 张金树, 张天平, 徐志忠, 范安辉, 索朗旺钦. 2012. 西藏改则县多不杂斑岩型铜金矿床勘查模型 [J]. 地质与勘探, 48(2): 274−287.

李玉彬, 钟婉婷, 张天平, 陈华安, 李玉昌, 陈红旗, 范安辉. 2012. 西藏改则县波龙斑岩型铜金矿床地球化学特征及成因浅析 [J]. 中国地质, 33(4): 579−587.

乔东海, 赵元艺, 汪傲, 李玉彬, 郭硕, 王松. 2017. 西藏多龙矿集区地堡铜 (金) 矿床年代学、流体包

裹体、地球化学特征及其成因类型研究方向 [J]. 地质学报, 91(7): 1542−1564.

方向, 唐菊兴, 丁帅, 王勤, 杨超, 唐攀. 2013. 西藏多龙矿集区尕尔勤岩石地球化学特征及构造环境 [J]. 矿物学报, 33(S2): 306−307.

唐菊兴, 宋扬, 王勤, 林彬, 杨超, 郭娜, 方向, 杨欢欢, 王艺云, 高轲, 丁帅, 张志, 段吉琳, 陈红旗, 粟登逵, 冯军, 刘治博, 韦少港, 贺文, 宋俊龙, 李彦波, 卫鲁杰. 2016. 西藏铁格隆南铜 (金银) 矿床地质特征及勘查模型-西藏首例千万吨级斑岩-浅成低温热液型矿床 [J]. 地球科学, 37(6): 663−690.

王勤, 林彬, 唐菊兴, 宋扬, 李彦波, 侯俊富, 李玉彬, 卫鲁杰. 2018. 多龙矿集区色那东岩体年龄、成因与动力学背景 [J]. 地球科学, 43(4): 1125−1141.

杨欢欢, 李玉彬, 杨超, 王勤. 2014. 西藏多龙矿集区拿厅矿段脉体类型及特征 [J]. 矿床地质, 33(S1): 51−52.

doi: 10.12029/gc2019Z103

Article Citation: Zhong Wanting, Li Yubin, Li Yuchang, Liu Chaoqiang, Chen Xiaoshen. 2019. Dataset of Resource Reserves in Duobuza Porphyry Copper Deposit of Tibet[J]. Geology in China, 46(S1):24−41.

Dataset Citation: Zhong Wanting; Li Yubin; Li Yuchang; Liu Chaoqiang; Chen Xiaoshen. Dataset of Resource Reserves in Duobuza Porphyry Copper Deposit of Tibet(V1). Chengdu University of Technology; Chengdu Center, China Geological Survey; The Fifth Geological Team of Tibet Bureau of Geology and Mineral Exploration[producer], 2005. National Geological Archives of China [distributor], 2019-06-30. 10.23650/data.C.2019.P2; http://dcc.ngac.org.cn/geologicalData/rest/geologicalData/geologicalDataDetail/91226d55f54252af86c6c381b0f6dcb3

Received: 10-08-2018
Accepted: 23-04-2019

Fund Project:
China Geological Survey Project "Comprehensive Integration and Services of Mineral Geology and Metallogenic Regularities in China (Mineral Geology Annals)" (DD20160346, DD20190379)

Dataset of Resource Reserves in Duobuza Porphyry Copper Deposit of Tibet

ZHONG Wanting [1,2], LI Yubin [1,3*], LI Yuchang [3], LIU Chaoqiang [3], CHEN Xiaoshen [3]

(1. *Chengdu University of Technology*, *Chengdu* 610059, *China*; 2. *Chengdu Center*, *China Geological Survey*, *Chengdu* 610081, *China*; 3. *The Fifth Geological Team of Tibet Bureau of Geology and Mineral Exploration*, *Golmud* 816000, *China*)

Abstract: Duobuza Copper Deposit in Tibet, the first large-scale porphyry copper deposit discovered along Pangong Lake−Nujiang River metallogenic belt in recent years, is situated in Duobuza tectonic magmatic arc in the northern margin of Pangong Lake−Nujiang River suture zone. It was formed during the evolution period of archipelagic arc-basin system of Pangong Lake−Nujiang River of Early Cretaceous with metallogenic age of 120 Ma. The deposit is related to quartz diorite porphyrite and granodiorite-porphyry intrusions in the strata of Meiriqiecuo Formation of Early Cretaceous. Boasting of present measured resources of Cu and Au of 2.30 million tonnes and 92 tonnes with average grade of 0.51% and 0.2 g/t respectively, Duobuza Copper Deposit ranks as one of the super large-scale deposits and one of the national strategic reserve bases of mineral resources. The dataset of resource reserves in Duobuza Porphyry Copper Deposit of Tibet is built based on the valuable data obtained in the mineral survey during 2005−2010. It contains 10 data tables, in which the grades and relevant calculated results of single-engineering industrial ore bodies and low-grade ore bodies in Duobuza Copper Deposit are mainly included. Furthermore, all detailed data related to reserve calculation are summarized and collated systematically in the dataset.

Key words: Tibet; Duobuza Copper Deposit; Grade; Resource reserves; Dataset

Data service system URL: http://dcc.cgs.gov.cn

1 Introduction

Duobuza Copper Deposit was discovered by the Fifth Geological Team of Tibet Bureau of Geology and Mineral Exploration during survey and assessment of placer gold in 1997.

About the first author: ZHONG Wanting, female, born in 1982, engineer, mainly engages in the research of metallogenic regularities and metallogenic prediction; E-mail: 67027693@qq.com.

The corresponding author: LI Yubin, male, born in 1982, senior engineer, mainly engages in exploration and evaluation of deposits; E-mail: liyb73@163.com.

With continuous investment in geological survey in the area, a new batch of mineral localities have been found around Duobuza Copper Deposit such as Cu (Au) polymetallic deposits of Bolong, Naruo, Nadun, Dibaonamugang, Tiegelongnan (Rongna), Sena, Gaerqin, Saijiao, and Nating (Li YB et al., 2012a, b; Fang X et al., 2013; Yang HH et al., 2014; Li GM et al., 2015; Li XK et al., 2015; Tang JX et al., 2016; Gao K et al., 2011; Qiao DH et al., 2017; Wang Q et al., 2018). In this way, Duolong Cu-Au Ore Concentration Area was formed. Among these deposits, four deposits including Duobuza, Bolong, Naruo, and Tiegelongnan (Rongnan), especially Duobuza Copper Deposit due to its high grade and shallow burial depth, have been ranked as super large-scale deposits. Presently, Duolong Ore Concentration Area has been explored at the highest degree along Pangong Lake−Nujiang River metallogenic belt. The discovery and research of Duolong Ore Concentration Area can provide rich basic information and data for in-depth research into copper polymetallic metallogenic belt in the west part of Pangong Lake−Nujiang River metallogenic belt and for the construction of non-ferrous metal reserve bases in northwest Tibet.

A significant breakthrough has been made in the copper polymetallic survey in the western part of Pangong Lake−Nujiang River metallogenic belt of Tibet in recent years. As the main working area, Duolong Ore Concentration Area is distributed in the trend of nearly NE from Anglong in the east to Dibaonamugang in the west, with Duobuza−Bolong Deposit Area as the center. Duolong Ore Concentration Area extends within 83°15′ ~ 83°45′ of east longitude and 32°45′ ~ 32°54′ of north latitude. It is about 45 km long from east to west and roughly 20 km wide from south to north, with an area of about 900 km^2 (Fig. 1).

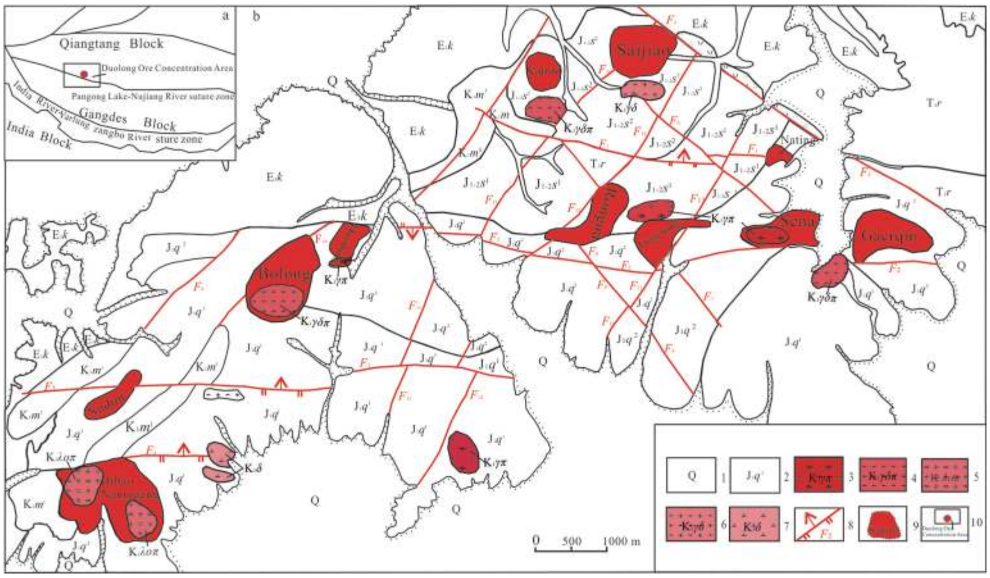

Fig. 1 Geological sketch of Duolong Ore Concentration Area (after Li YB et al., 2012)

a. Regional location sketch of Duolong Ore Concentration Area; b. Geological sketch of Duolong Ore Concentration Area. 1−Quaternary; 2−Stratum code; 3−Granite porphyry of Early Cretaceous; 4−Granodiorite porphyry of Early Cretaceous; 5−Quartz porphyry of Early Cretaceous; 6−Granodiorite of Early Cretaceous; 7−Diorite of Early Cretaceous; 8−Normal fault; 9−Deposit area and its name; 10−Regional location of Duolong Ore Concentration Area

The brief metadata table of the dataset of resource reserves in Duobuza deposit area of Tibet is shown in Table 1.

Table 1 Metadata Table of Database (Dataset)

Items	Description
Database (dataset) name	Dataset of Resource Reserves in Duobuza Porphyry Copper Deposit of Tibet
Database (dataset) authors	Zhong Wanting, Chengdu University of Technology; Chengdu Center, China Geological Survey Li Yubin, Chengdu University of Technology, the Fifth Geological Team of Tibet Bureau of Geology and Minerals Exploration Li Yuchang, the Fifth Geological Team of Tibet Bureau of Geology and Minerals Exploration Liu Chaoqiang, the Fifth Geological Team of Tibet Bureau of Geology and Minerals Exploration Chen Xiaoshen, the Fifth Geological Team of Tibet Bureau of Geology and Minerals Exploration
Data acquisition time	2005—2010
Geographic area	Duobuza Deposit Area, Gaize County, Tibet
Data format	*.docx
Data size	9.54 MB
Data service system URL	http://dcc.cgs.gov.cn
Fund project	China Geological Survey Project "Comprehensive Integration and Services of Mineral Geology and Metallogenic Regularities in China (Mineral Geology Annals)" (DD20160346, DD20190379).
Language	Chinese
Database (dataset) composition	The dataset of resource reserves in Duobuza Deposit Area of Tibet contains 10 data tables in Word format named *Basic Information of Single-Engineering Ore Bodies*, *Calculation Results of Average Grades of Single Engineering Industrial Ore Bodies and Low-Grade Ore Bodies*, *Information of Connection Area of Ore Bodies, Calculation Results of Profile Area Between Adjacent Exploratory Lines of Blocks, Calculation Results of Block Grades by Weighted Average, Estimated Results of Resource Reserves of Blocks, Summary of Estimated Resources of Ore Bodies, Calculation Results of Average Volumetric Weight, Calculation Results of Variation Coefficients of Ore Body Grades*, and *Calculation Results of Variation Coefficients of Ore Body Thickness* respectively.

2 Geology of Duobuza Porphyritic Copper Deposit

Duobuza Porphyritic Copper Deposit, with an area of roughly 8.66 km^2, ranks as grade I exploration type. A basic density of exploration grid of (200 ~ 400) × (100 ~ 200) m was adopted in the reconnaissance survey of the area. Then a porphyritic copper ore body was delineated in the area on the basis of surficial and deep mining engineering (including shallow wells, trenching, and drilling). The ore body outcrops between the exploration lines No. 39 and No. 24, stretches in the strike of nearly E—W, and dips steeply towards the south. It is characterized by a tabular body with huge thickness in terms of appearance, with a dip angle of 40° ~ 60° and the controlled ore body of being 1 600 m long, 200 ~ 500 m thick, and 200 ~ 600 m wide.

The ore body mainly exists in the potassic zone and the sericite-quartz alteration zone above granodiorite porphyry body, and in the propylitized feldspathic quartz sandstone on the side of the granodiorite porphyry body. In the porphyry body, the copper mineralization is mainly disseminated and veinlet chalcopyrite mineralization. In the inner and outer contact parts between the porphyry body and the surrounding rocks, the copper mineralization is mainly veined and net-veined chalcopyrite mineralization, with copper grade increasing greatly. In the outside propylitized feldspathic quartz sandstone, the copper mineralization is mainly veined, veinlet-like and disseminated chalcopyrite mineralization, with copper grade decreasing gradually. The average grades of Cu and Au of the ore body are 0.51% and 0.2 g/t, respectively.

The average grade of copper in the orebody changes greatly in the trend of E—W, higher at the exploration lines with numbers of 23, 07, 00, 08 and 16 ranging from 0.5% to 0.73% (Fig. 2), and lower in the exploration lines with numbers of 31, 15 and 24 ranging from 0.27% to 0.35%. Therefore, it is generally characterized by high grade in the middle and low grade in the east and west (Table 2). The copper grade of the orebody also changes greatly vertically and is generally featured by high grade in the porphyry body and near the contact zone and low grade in propylitized feldspathic quartz sandstone. Further, the grades of Cu and Au are clearly in positive correlation (Fig. 3). Among these exploration lines, the borehole of exploration line No. 23 is drilled to 601.41 m in depth, not penetrating the ore body with deepening up to 565.31 m in the controlled orebody. However, the borehole of the exploration line No. 31, which is just 200 m distant from the exploration line No. 23, is drilled to 356.41 m in depth with deepening of only 22 m in the controlled orebody near the ground surface. A similar condition occurs to lines No. 16 and line No. 24. This suggests that the ore body is complex in morphology.

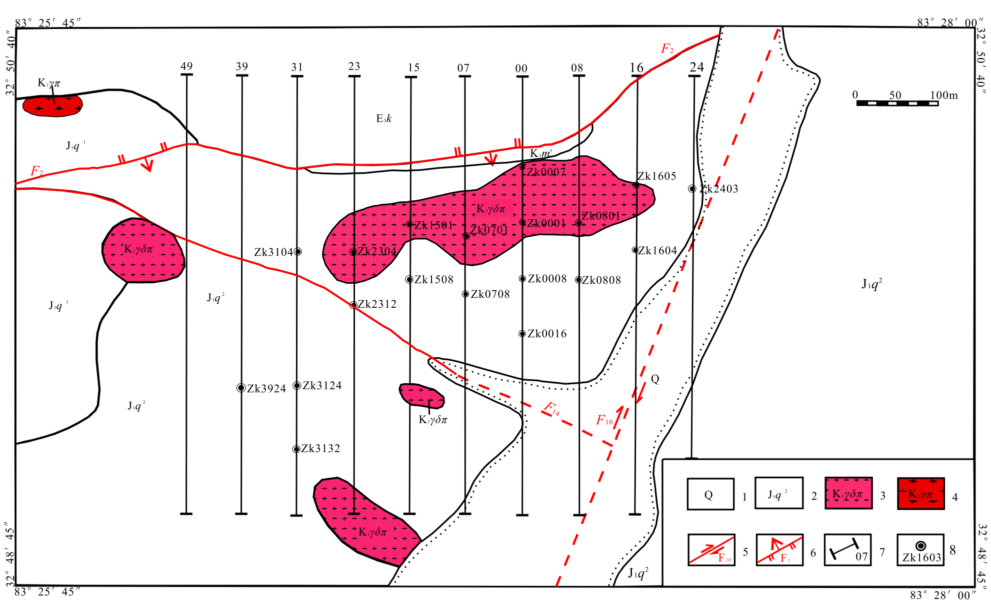

Fig. 2 Profile of the exploration line No. 0 in Duobuza Deposit Area

1−Stratum code; 2−Granodiorite porphyry of Early Cretaceous; 3−Strike-slip fault; 4−Borehole and its number; 5−Industrial ore body; 6−Low-grade ore body

Table 2 Statistics of Ore-Discovery Characteristics Based on Drilling Engineering

Exploration line	No.31	No.23	No.15		No.07		No.00		No.08		No.16		No.24	**Remarks**
Engineering No.	3104	2304	1501	1508	0701	0708	0001	0008	0801	0808	1605	1604	2405	
Cu grade of single engineering (%)	0.27	0.73	0.38	0.29	0.86	0.30	1.01	0.36	0.69	0.31	0.77	0.26	0.35	
Au grade of single engineering o (g/t)	–	0.30	–	–	0.41	0.17	0.46	0.13	0.43		0.16		0.12	
Thickness of a single engineering ore body (m)	22	565.31	88.48	380.4	283.06	226.74	222.32	393.04	196	401.61	379.40	395	92.56	The engineering with numbers of 2304, 1508, 0808, 1604, and 1605 did not penetrate the ore body
Cu average grade determined by least squares fitting method (%)	0.27	0.73	0.34		0.63		0.68		0.50		0.52		0.35	
Au average grade of the engineering determined by least squares fitting method (g/t)	–	0.30	–		0.29		0.30		–		–		0.12	
Thickness of ore body of the exploration line (m)	22	565.31	235.44		255.9		307.78		298.80		387.2		92.56	

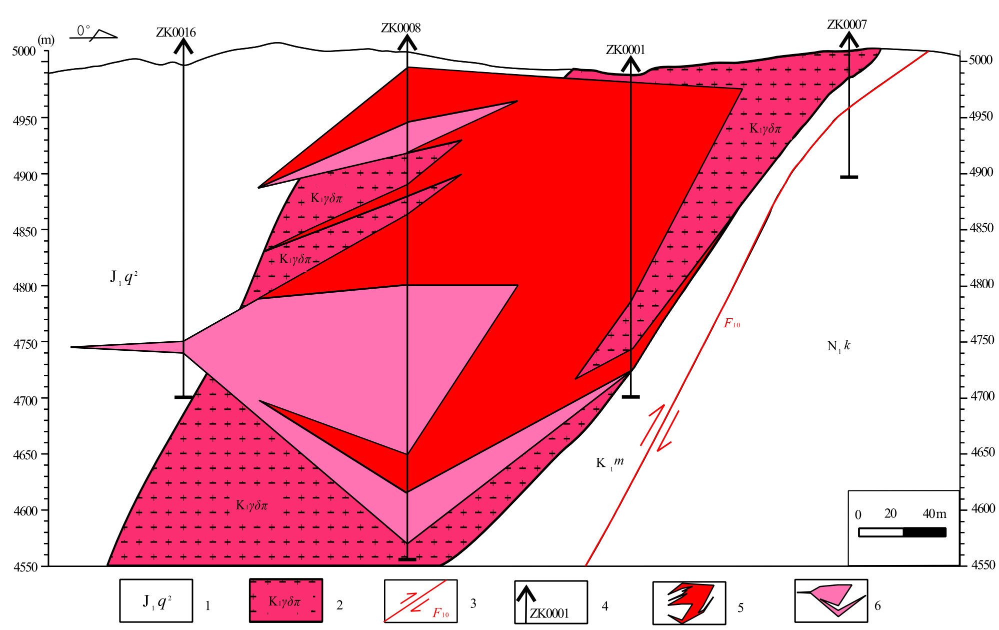

Fig. 3 Exploration line layout in Duobuza Copper Deposit (after Li YB et al., 2012a)

1− Quaternary; 2−Stratum code; 3−Granodiorite porphyry of Early Cretaceous; 4−Granite porphyry of Early Cretaceous; 5−Strike-slip fault; 6−Normal fault and its number; 7−Exploration line and its number; 8−Borehole and its number;

As for the ore bodies on the top of Duobuza Copper Deposit, secondary enrichment zones bear in local areas due to oxidation, with the primary deposit as dominant ore bodies. The ore bodies are mainly distributed in the porphyry body as well as the inner and outer contact zones between the ore bodies and altered surrounding rocks, with mineralization of whole rock as dominant mineralization type and fine grained, micro-fine grained and veinlet disseminated ores as the main forms. Mineralization at the highest degree occurs near the inner and outer contact zones, with veined and net veined ores as the dominant forms. Disseminated ores are mainly distributed in the surrounding rocks of the ore bodies, and the grade decreases towards the outside gradually. The ore bodies in Duobuza Copper Deposit mainly consist of primary ores, with chalcopyrite as main copper mineral and malachite, azurite, and chalcocite outcropping on the ground surface. The chalcopyrite is brassy in color and bears in granodiorite porphyry and sandstones in forms of xenomorphic granular, disseminated, and veinlet-like aggregates. The malachite and azurite are hosted in granodiorite porphyry or cataclastic sandstones, showing as thin-layered, fibrous aggregated, dusted and lumpy aggregated, or spotted. A small amount of chalcocite is visible locally.

3 Method for Data Acquisition and Processing

3.1 Sampling

Drilling core sampling: each drilling core were cut into two parts with a core cutting machine in the core warehouse. The core samples were taken continually from start to the end of drilling. The length of the samples was 2 m long in principal and was basically controlled within 2±0.5 m, although it can be increased or decreased depending on actual conditions (e.g. crossing strata). A total of 11 929 rock core samples and ore core samples were collected.

Small-volumetric-weight samplling: samples were taken from duplicate samples of cores taken in boreholes and were taken separately according to different ore types. A total of 65 small-volumetric-weight samples were collected in the field. They were preserved by wax sealing and then sent to labs for testing.

3.2 Analytical Method

The Fifth Sub-lab of the Central Lab of Tibet Bureau of Geology and Mineral Exploration with the qualification of Level A of National Experimental Analysis was entrusted with sample tests. The samples subject to external inspection were sent to and then analyzed by the former Chengdu Supervision and Inspection Center of Mineral Resources, Ministry of Land and Resources and the former Shenyang Supervision and Inspection Center of Mineral Resources, Ministry of Land and Resources, both of which were qualified as Level A of National Experimental Analysis. Conventional immersion specific gravity measurement and analytical method was conducted on volumetric-weight samples, and conventional methods were employed for chemical analysis.

3.3 Estimation Method of Resource Reserves

3.3.1 Industrial Indices Adopted

Duobuza Deposit Area is situated in the hinterland in the northern Tibetan plateau. The main ore bodies in the area subject to estimation of resources are suitable to be mined in an opencast manner due to their steep occurrence and huge thickness. Furthermore, the outcrops are significantly physically weathered, and most ores are sulfide ores. Therefore, the following industrial indices were finally determined according to the specifications such as *Specifications for Copper, Lead, Zinc, Silver, Nickel and Molybdenum Mineral Exploration* (DZ/T 0214−2002) and *Technical Requirements for Estimation of Intrinsically Economic Resources Inferred from Solid Ores and Predicted Resources According to Engineering Verification* (DD 2002−1) as well as the characteristics of the ores in the main ore body and future mining methods in the area.

Cutoff grade (Cu): 0.2%;

Minimum industrial grade (Cu): 0.4%;

Minimum minable thickness: ⩾ 4 m;

Band rejected thickness: ⩾ 8 m;

Average grades of associated useful components: Au (g/t): 0.1; Ag (g/t): 1.0.

3.3.2 Estimation Method Selection of Resource Reserves

According to applicable specifications, the mineral exploration type shall be determined according to five main geological factors, i.e. ore body scale, morphology and internal structure of the main ore body, structutal influence, thickness stability of the main ore body, and distribution of useful components. To quantify the influence of these factors, type coefficients are introduced and each influential coefficient is assigned a certain value. In this way, the exploration type can be rationally determined according to the sum of the type coefficients from the five geological factors. As stipulated in the applicable specifications, exploration type is grade I if the sum of the type coefficients from the five geological factors ranges from 2.5 to 3.0. Therefore, the exploration type of the Duobuza Copper Deposit is grade I for that the sum of its type coefficient is 2.8.

3.3.3 Main Parameter Determination for Resources Estimation

The vertical parallel cross-section method was adopted to estimate resources, and the parameters selected include grade, thickness, area, volume, volumetric weight, ore content, and metal content. In terms of calculation precision, the calculations of the grade, thickness, and volumetric weight were accurate to two decimal places, and the calculations of the area, volume, ore content, and metal content were accurate to form an integer. Rounding up was adopted for all these parameters.

1) Grade

(1) Average grade of a single engineering ore body

The samples delineated into the ore bodies in Duobuza Copper Deposit vary little in length. Therefore, the average grade of a single engineering ore body was calculated by the weighted average method with the grades and lengths of all the samples delineated into the ore bodies in the area as independent variables.

(2) Average grade of a profile

Weighted average method was adopted to calculate the average grade of a profile with the single engineering thicknesses (apparent thickness) of all adjacent ore bodies on the profile as independent variables.

(3) Average grade of a block

It is calculated by weighted average method with the average grades of the profiles in the block and profile areas as independent variables.

(4) Average grade of an ore body

It is calculated by dividing the metal content of the ore body by ore content of the ore body.

(5) Average grade of a deposit

It is calculated by dividing metal content by ore content in the deposit.

(6) Processing of extra-high grade

According to applicable regulations, " extra-high grade refers to the grade of a single sample which is 6 ~ 8 times higher than the average grade of a deposit (ore body)." The extra-high grade is processed in the following way: "determining the block or the single engineering ore body affected by the extra-high grade, calculating the average grade of the block or the single engineering ore body with the extra-high grade, and then replaces the extra-high grade with the average grade calculated above to calculate the average grade of a block or a single engineering ore body" . The determined extra-high grade of Duobuza Copper Deposit is 0.513% × 8 = 4.12%. All boreholes have the grades less than the extra-high grade except the borehole ZK0001, in which the copper grade is greater than the extra-high grade. The area surrounding borehole ZK0001 was regarded as ore enrichment part according to related geological regularities and the fact that the grade is high continuously in ZK0001. Therefore, there are no extra-high grades in Duobuza Copper Deposit.

2) Area

The profile area (S) was directly calculated by using a computer software and then numbered. The industrial ore bodies and low-grade ore bodies were divided into different block cross-sections and numbered from left to right and from up to bottom in the resources estimation profile according to the sequence of the exploration lines from west to east.

3) Volume

The calculation of the volume of the block between parallel profiles

The volume between adjacent profiles was calculated with the formula below:

$$V = \frac{1}{2}(S_1 + S_2) \times L (for\ area\ difference < 40\%)$$

$$V = \frac{1}{3}\left(S_1 + S_2 + \sqrt{S_1 \times S_2}\right) \times L (for\ area\ difference > 40\%)$$

Where, V refers to the volume of a block, S_1 and S_2 refer to the areas of two adjacent profiles of the same block, L refers to the vertical distance between two adjacent profiles.

The volume of boundary profiles is calculated with the following formula extrapolated:

$V = \frac{1}{2} S \times L$ (for wedge-shape profiles)

$V = \frac{1}{3} S \times L$ (for cone-shape profiles)

Where, S refers to profile area, L refers to the vertical distance from the point extrapolated to its adjacent profile.

4) Volumetric weight

The volumetric weight of ores in a deposit area is the arithmetic mean of the data measured of small-volumetric-weight ore samples obtained in the area. The average volumetric weight of the ores in Duobuza Copper Deposit is 2.58 t/m^3.

5) Ore content

The ore content was calculated by multiplying volume and average volumetric weight. The formula adopted is $q=s\times t\times d$,

Where, q refers to ore resources in an ore body (t), s refers to the area of the ore body (m^2), t refers to the average thickness of the ore body (m), and d refers to the volumetric weight of the ore body (t/m^3).

6) Metal content

The metal content was calculated by multiplying the ore content and its average grade. The formula adopted is $p=q\times c$,

Where, p refers to the metal content in an ore body (t) and c refers to the average grade of copper ore body (%).

3.3.4 Resources Classification and Block Division Principle

The inferred intrinsically economic resources (333) and prognostic intrinsically economic resources (334) were determined according to *Interim Provisions for Reconnaissance Survey of Solid Minerals* (DD 2000−02) and *Interim Provisions for Pre-investigation of Solid Minerals* (*DD 2000−01*) as well as the document with No. of [2002] 234.44 (*Technical Requirements for Estimation of Intrinsically Economic Resources Inferred from Solid Ores and Predicted Resources According to Engineering Verification*) (DD 2002−1) issued by China Geological Survey.

1) Classification of Resources

The engineering arrangement in Duobuza Copper Deposit was implemented in accordance with the *Specification for Geological Exploration* (2003), a geological mineral industry standard issued by the former Ministry of Land and Resources. Unmask ground was conducted through shallow wells and trenches with the grid density of 100×100 m, and then the mineralization range was delineated. Based on this, sparse control was carried out through 19 boreholes of the exploration lines with numbers of 0, 7, 8, 15, 16, 23, 24, 31, and 39 with grid density of (200~400) × (200~400) m. In addition, copper ore bodies were found in 18 boreholes.

The type of resources satisfying the grid density of 400×400 m in the engineering control area is 333 and the type of resources determined as per infinite distance extrapolation of basic grid density of 400×400 m is 334, in which 200 m of pinchout extrapolation is involved.

2) Block Division

The division principle of blocks is that a natural block is formed by connecting the engineering points of the same type of resources in the same ore body between the profiles of adjacent exploration lines. On the basis of types of resources, the blocks were numbered by ore body types from left to right and from up to bottom in the resources estimation plan. The resources were respectively estimated according to two ore-body types in Duobuza Copper Deposit, i.e. industrial ore body and low-grade ore body. The industrial ore bodies were divided into 16 natural blocks and the low-grade ore bodies were divided into 28 natural blocks.

4 Description of Data Samples

The data table named *Basic Information of Single-Engineering Ore Bodies* contains the following data (Table 3): ore body number, exploration line number, engineering number, sample number, sampling location, sample length, sample analysis result, product of sample length and grade, sum of product of length and grade of each sample, ore body thickness, average grade, and remarks.

Table 3 Structure of data table named *Basic Information of Single-Engineering Ore Bodies*

No.	Field name	Unit	Data type	Example
1	Ore body number	–	Char	I
2	Exploration line number	–	Char	39
3	Engineering number	–	Char	ZK3924
4	Sample number	–	Char	H48
	Sampling location	m	Char	–
5	From	m	Float	93.12
	To	–	Float	95.12
6	Sample length	m	Float	2
	Sample analysis result	–	Float	–
7	Cu	%	Float	0.36
	Au	g/t	Float	0.1
	Product of sample length and grade	–	Float	–
8	Cu	–	Float	0.72
	Au	–	Float	0.19
	Sum of product of length and grade of each sample	–	Float	–
9	Cu	–	Float	7.84
	Au	–	Float	2.35
10	Ore body thickness	m	Float	14
	Average grade	–	Float	–
11	Cu	%	Float	0.56
	Au	g/t	Float	0.17
12	Remarks	–	Char	–

The data table named *Calculation Results of Average Grades of Single Engineering Industrial Ore Bodies and Low-Grade Ore Bodies* contains the following data (Table 4): engineering number, ore body type, overall ore body, industrial ore body, low-grade ore body, sample number, sampling location, ore-discovery thickness of ore bed, product of grade and ore-discovery thickness of ore bed, average grade of ore bed, ore-discovery thickness of single engineering, sum of products of ore-discovery thickness and grade of single engineering, and average grade of single engineering.

Table 4 Structure of data table named *Calculation Results of Average Grades of Single Engineering Industrial Ore Bodies and Low-Grade Ore Bodies*

No.	Field name	Unit	Data type	Example
1	Ore body type	–	Char	ZK3924
2	Overall ore body	–	Char	–
	Industrial ore body	–	Float	38.6
	Low-grade ore body	–	Float	22
	Sample number	–	Float	16.6
3	Ore body type	–	Char	–
	From	m	Float	H48
	To	m	Float	H54
4	Sampling location	m	Float	–
	From	m	Float	93.12
	To	m	Float	107.12
5	Ore-discovery thickness of ore bed	m	Float	14
6	Product of grade and ore-discovery thickness of ore bed		Float	–
	$\sum Cu^{*}H$		Float	7.84
	$\sum Au^{*}H$		Float	2.53
7	Average grade of ore bed		Float	–
	Cu	%	Float	0.56
	Au	g/t	Float	0.17
8	Ore-discovery thickness of single engineering	m	Float	–
	Overall ore body	m	Float	38.6
	Industrial ore body	m	Float	22
	Low-grade ore body	m	Float	16.6
9	Sum of products of ore-discovery thickness and grade of each single engineering	–	Float	–
	Overall ore body (Cu)	%	Float	15.88
	Industrial ore body (Cu)	%	Float	12.16
	Low-grade ore body (Cu)	%	Float	3.72
	Overall ore body (Au)	g/t	Float	10.45
	Industrial ore body (Au)	g/t	Float	8.53
	Low-grade ore body (Au)	g/t	Float	1.91

Continued table 4

No.	Field name	Unit	Data type	Example
10	Average grade of single engineering	–	Float	–
	Overall ore body (Cu)	%	Float	0.41
	Industrial ore body (Cu)	%	Float	0.55
	Low-grade ore body (Cu)	%	Float	0.22
	Overall ore body (Au)	g/t	Float	0.27
	Industrial ore body (Au)	g/t	Float	0.36
	Low-grade ore body (Au)	g/t	Float	0.12
11	Remarks	–	Char	–

The data table named *Information of Connection Area of Ore Bodies* contains the following data (Table 5): exploration line number, ore body number, grade, area number, gross area, net area, inner casing area, and average grade.

Table 5 Structure of data table named *Information of Connection Area of Ore Bodies*

No.	Field name	Unit	Data type	Example
1	Exploration line number	–	Char	0
2	Ore body number	–	Char	DBZM1
3	Grade	–	Char	Industrial ore body
4	Area No.	–	Char	0_13
5	Gross area	–	–	39 676.7
6	Net area	–	–	35 696.24
7	Inner casing area	–	–	3 980.46
8	Average grade	–	–	–
	Cu	%	–	0.85
	Au	g/t	–	0.32

The data table named *Calculation Results of Profile Area Between Adjacent Exploratory Lines of Blocks* contains the following data (Table 6): ore body number, block number, engineering constituting block, spatial morphology of block, profile area of block, and distance between profiles.

Table 6 Structure of data table named Calculation *Results of Profile Area Between Adjacent Exploratory Lines of Blocks*

No.	Field name	Unit	Data type	Example
1	Ore body number	–	Char	DBZM1
2	Block number	–	Char	DBZ08
3	Engineering constituting block	–	Char	–
	Engineering constituting area S1	–	Char	Zk1501
		–	Char	Zk1508
	Engineering constituting area S2	–	Char	Zk0701
		–	Char	Zk0708

Continued table 6

No.	Field name	Unit	Data type	Example
4	Spatial morphology of block	–	Char	Truncated cone
5	Profile area of block	–	Char	–
	Area No.1	–	Char	15_4,15_9,15_12,15_13
	S_1	m^2	Float	3 544.63
	Area No. 2	–	Char	7_43
	S_2	m^2	Float	36 097.01
6	Distance between profiles	m	Float	200

The data table named *Calculation Results of Block Grades by Weighted Average* contains the following data (Table 7): ore body number, block number, reserve type, spatial morphology of block, profile area of block, average grade of Cu, average grade of S_1 (Cu%), average grade of S_2 (Cu%), average grade of block (Cu%), average grade of S_1 (Au g/t), average grade of Au, average grade of S_2 (Au g/t), and average grade of block (Au g/t).

Table 7 Structure of data table named *Calculation Results of Block Grades by Weighted Average*

No.	Field name	Unit	Data type	Example
1	Ore body number	–	Char	DBZM1
2	Block number	–	Char	DBZ06
3	Reserve type	–	Char	334
4	Spatial morphology of block	–	Char	Truncated cone
5	Profile area of block	m^2	Float	–
	S_1	m^2	Float	31 788.63
	S2	m^2	Float	4 489.77
6	Average grade (Cu)	%	Float	–
	Average grade of s1	%	Float	0.56
	Average grade of s2	%	Float	0.42
	Average grade of block	%	Float	0.55
7	Average grade (Au)	g/t	Float	–
	Average grade of s1	g/t	Float	0.27
	Average grade of s2	g/t	Float	0.08
	Average grade of block	g/t	Float	0.25

The data table named *Estimated Results of Resource Reserves of Blocks* contains the following data (Table 8): ore body number, reserve type, block number, block profile area, spatial morphology of block, distance between profiles, total volume of block, volumetric weight, ore content, average grade (Cu), metal content (Cu), average grade (Au), and metal content (Au).

Table 8 Structure of data table named *Estimated Results of Resource Reserves of Blocks*

No.	Field name	Unit	Data type	Example
1	Ore body number	–	Char	DBZM1
2	Reserve type	–	Char	333
3	Block number	–	Char	DBZ10
4	Block profile area	–	Char	–
	S_1	m^2	Float	86 017.58
	S_2	m^2	Float	3 544.63
5	Spatial morphology of block	–	Char	Truncated cone
6	Distance between profiles	m	Float	200
7	Total volume of block	m^3	Float	7 134 908.22
8	Volumetric weight	t/m^3	Float	2.58
9	Ore content	t	Float	18 408 063.2
10	Metal content (Cu)	–	Float	–
	Average grade	%	Float	0.71
	Metal content	t	Float	130 697.25
11	Metal content (Au)	–	Float	–
	Average grade	g/t	Float	0.28
	Metal content	kg	Float	5 154.26

The data table named *Summary of Estimated Resources of Ore Bodies* contains the following data (Table 9): ore body number, grade, reserve type, ore body volume, ore content, average grade (Cu), resources (Cu), average grade (Au), resources (Au), and remarks.

Table 9 Structure of data table named *Summary of Estimated Resources of Ore Bodies*

No.	Field name	Unit	Data type	Example
1	Ore body number	–	Char	DBZM1
2	Grade	–	Char	Industrial ore body
3	Reserve type	–	Char	333
4	Ore body volume	m^3	Float	57 190 409.3
5	Ore content	t	Float	147 551 256
6	Average grade (Cu)	%	Float	0.74
7	Resources (Cu)	t	Float	1 096 826.83
8	Average grade (Au)	g/t	Float	0.28
9	Resources (Au)	kg	Float	40 609.16
10	Remarks		Char	–

The data table named *Calculation Results of Average Volumetric Weight* contains the following data (Table 10): field number, analysis results (ore weight, sealing wax weight, buoyant weight, and ore density), sampling location, lithology, chemical analysis result (w(Cu), w(Au)), and average volumetric weight.

Table 10 Structure of data table named *Calculation Results of Average Volumetric Weight*

No.	Field name	Unit	Data type	Example
1	Field number	–	Char	BT1
2	Analysis results	–	Float	–
	Ore weight	g	Float	111
	Sealing wax weight (g)	g	Float	113
	Buoyant weight	g	Float	66.5
	Ore density	g/cm^3	Float	2.51
3	Sampling location	–	Float	ZK0701-27 m
4	Lithology	–	Char	Granodiorite porphyry
5	Chemical analysis result	–	Float	–
	w(Cu)	%	Float	1.45
	w(Au)	g/t	Float	0.43
6	Average volumetric weight	g/cm^3	Float	2.58

The data table named *Calculation Results of Variation Coefficients of Ore Body Grade*s contains the following data (Table 11): engineering number, average grade of single engineering, number of engineering, sum of average grades of single engineering of ore body, arithmetic average grade of single engineering of ore body, difference between average grade of single engineering and the arithmetic average grade of single engineering of ore body, difference square, sum of difference squares, mean square deviation, variation coefficient, and remarks.

Table 11 Structure of data table named *Calculation Results of Variation Coefficients of Ore Body Grades*

No.	Field name	Unit	Data type	Example
1	Engineering number	–	Char	ZK3924
2	Average grade of single engineering	–	Float	–
	Cu(Au)	%	Float	0.41
3	Number of engineering	n	Float	17
4	Sum of average grades of single engineering of ore body	%	Float	8.09
5	Arithmetic average grade of single engineering of ore body	%	Float	0.48
6	Difference between average grade of single engineering and the arithmetic average grade of single engineering of ore body	%	Float	−0.07
7	Difference square	%	Float	0.004 7
8	Sum of difference squares	%	Float	0.937 7
9	Mean square deviation	%	Float	0.242 1
10	Variation coefficient	%	Float	50.85%
11	Remarks	–	Char	Adopting *n*-1 when *n*<25

The data table named *Calculation Results of Variation Coefficients of Ore Body Thickness* contains the following data (Table 12): engineering number, ore-discovery thickness of single engineering, number of engineering, sum of ore-discovery thicknesses of single engineering, arithmetic mean of ore-discovery thicknesses of single engineering, difference between the ore-discovery thickness of single engineering and the arithmetic mean of ore-discovery thicknesses of single engineering, difference square, sum of difference squares, mean square deviation, variation coefficient, and remarks.

Table 12 Structure of data table named *Calculation Results of Variation Coefficients of Ore Body Thickness*

No.	Field name	Unit	Data type	Example
1	Engineering number	–	Char	ZK3924
2	Ore-discovery thickness of single engineering	m	Float	38.6
3	Number of engineering	n	Float	17
4	Sum of ore-discovery thicknesses of single engineering	m	Float	4 117.55
5	Arithmetic mean of ore-discovery thicknesses of single engineering	m	Float	242.21
6	Difference between the ore-discovery thickness of single engineering and the arithmetic mean of ore-discovery thickness of single engineering	m	Float	−203.61
7	Difference square	m	Float	41 457.03
8	Sum of difference squares	m	Float	429 146.69
9	Mean square deviation	m	Float	163.77
10	Variation coefficient	%	Float	67.62%
11	Remarks.	–	Char	Adopting n-1 when $n<25$

5 Data Quality Control and Assessment

As a part of the project named *Survey and Evaluation of Strategic Mineral Resources* in the programs titled *Survey for Land and Resources* (2005—2007) and *Qinghai–Tibet Special Survey* (2008—2010), the dataset of resource reserves in Duobuza Porphyry Copper Deposit of Tibet contains valuable mineral survey data obtained based on a previous project named *Reconnaissance Survey of Duobuza Copper Deposit in Gaize County, Tibet*. The resource reserve report of the Duobuza Deposit Area was submitted in 2012. The data sources are authentic and credible. Resource reserves were calculated by the methods prevailing in China and abroad based on deposit types and actual conditions of ore bodies. Therefore, the calculation methods are feasible and appropriate. Relevant data will be maintained, calibrated and updated with continuous advancement of the subsequent survey in the area in future. In this way, the dataset is characterized by practicality, accuracy, and continuity in terms of data quality and thus is worthy of promotion.

6 Conclusion

Another great prospecting outcome in Pangong Lake–Nujiang River metallogenic belt in recent years can be reflected in the dataset of resource reserves in Duobuza Porphyry Copper Deposit of Tibet. As of the end of the dataset construction, more than 2.30 million tonnes of Cu and Au resources of types 333 and 334 and 92 tonnes of associated Au resources have been achieved in Duobuza Porphyry Copper Deposit, with Cu average grade of ore bodies of 0.51% and average grade of associated Au resource of 0.2 g/t. The survey and assessment of resource reserves in the deposit can provide references for the assessment of resource reserves of the surrounding deposits and for zoning and type division of the deposits of the same types in Pangong Lake–Nujiang River metallogenic belt.

Acknowledgements: We would like to extend our sincere appreciation to senior engineering Zhang Tianping and engineer Fan Anhui from the Fifth Geological Team of Tibet Bureau of Geology and Minerals Exploration for their guidance in making this paper a success. We would also like to extend our sincere appreciation to editor Zhang Xinyuan for his constructive and instructive opinions on the revision of this paper.

References

Fang Xiang, Tang Juxing, Ding Shuai, Wang Qin, Yang Chao, Tang Pan. 2013. Petrogeochemistry and tectonic environment of Ga’erqin rocks in Duolong, Tibet[J]. Acta Mineralogica Sinica, 33(S2): 306–307 (in Chinese).

Gao Ke, Tang Juxing, Song Yang, Liu Zhibo, Fang Xiang, Yang Huanhuan, Wang Qin, Lin Bin, Wang Yiyun. 2011. Genesis of Magmatic Rocks of Cryptoexplosive Breccia in the Naruo Deposit of Tibet: Evidence from Zir con Hf Isotope[J]. Geology and Exploration, 53(2): 207–216 (in Chinese with English abstract).

Li Guangming, Zhang Xianan, Qin Kezhang, Sun Xingguo, Zhao Junxing, Yin Xianbo, Li Jinxiang, Yuan Huashan. 2015. The telescoped porphyry-high sulfidation epithermal Cu (-Au) mineralization of Rongna deposit in Duol long ore cluster at the southern margin of Qiangtang Terrane, Central Tibet: Integrated evidence from geology, hydrothermal alteration and sulfide assemblages[J]. Acta Petrologica Sinica, 31(8): 2307–2324 (in Chinese with English abstract).

Li Xingkui, Li Cai, Sun Zhenming, Wu Hao. 2015. Zircon U-Pb geochronology, Hf isotope, and whole-rock geochemistry of diorite in the Saijiao Cu-Au deposit, Tibet, and its ore-forming significance[J]. Geological Bulletin of China, 34(5): 908–918 (in Chinese with English abstract).

Li Yubin, Duo Ji, Zhong Wanting, Li Yuchang, Qiang Bawangdui, Chen Hongqi, Liu Hongfei, Zhang Jinshu, Zhang Tianping, Xu Zhizhong, Fan Anhui, Suo Langwangqing. 2012. An Exploration Model of the Duobuza Porphyry Cu-Au Deposit in Gaize Country, Northern Tibet[J]. Geology and Exploration, 48(2): 274–287 (in Chinese with English abstract).

Li Yubin, Zhong Wanting, Zhang Tianping, Chen Huaan, Li Yuchang, Chen Hongqi, Fan Anhui. 2012. Geochemical Characteristics and Genesis of the Bolong Porphyry Copper-Gold Deposit in Gerze County, Tibet[J]. Acta Geoscientica Sinica, 33(4): 579–587 (in Chinese with English abstract).

Qiao Donghai, Zhao Yuanyi, Wang Ao, Li Yubin, Guo Shuo, Wang Song. 2017. Geochronology, Fluid Inclusions, Geochemical Characteristics of Dibao Cu (Au) Deposit, Duolong Ore C oncentration Area, Xizang (Tibet), and Its Genetic Type[J]. Acta Geologica Sinica, 91(7): 1542−1564 (in Chinese with English abstract).

Tang Juxing, Song Yang, Wang Qin, Lin Bin, Yang Chao, Guo Na, Fang Xiang, Yang Huanhuan, Wang Yiyun, Gao Ke, Ding Shuai, Zhang Zhi, Duan Jilin, Chen Hongqi, Su Dengkui, Feng Jun, Liu Zhibo, Wei Shaogang, He Wen, Song Junlong, Li Yanbo, Wei Lujie. 2016. Geological Characteristics and Exploration Model of the Tiegelongnan Cu(Au-Ag) Deposit: The First Ten Million Tons Metal Resources of a Porphyry-epithermal Deposit in Tibet[J]. Acta Geoscientica Sinica, 37(6): 663−690 (in Chinese with English abstract).

Wang Qin, Lin Bin, Tang Juxing, Song Yang, Li Yanbo, Hou Junfu, Li Yubin, Wei Lujie. 2018. Diagenesis, Lithogenesis and Geodynamic Setting of Intrusions in Senadong Area, Duolong District, Tibet[J]. Earth Science, 43(4): 1125−1141 (in Chinese with English abstract).

Yang Huanhuan, Li Yubin, Yang Chao, Wang Qin. 2014. Types and characteristics of the veins in the Nating mine section in Duolong, Tibet[J]. Mineral Deposits, 33(S1): 51−52 (in Chinese with English abstract).