全球锂·钴·镍·锡·钾盐矿产资源储量评估报告

Assessment Report for Lithium, Cobalt, Nickel, Tin, and Potash Reserves in the World

2021

中国地质调查局全球矿产资源战略研究中心
Research Center for Strategy of Global Mineral Resources,
China Geological Survey

全球锂、钴、镍、锡、钾盐
矿产资源储量评估报告（2021）

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前　言

本报告是中国研究机构首次评估和公布的全球矿产资源储量信息。

进入 21 世纪，全球矿产资源供需格局发生重大变化。西方发达国家资源需求趋于饱和，新兴工业化国家资源需求快速增长，资源需求的重心向东方转移，以新能源、信息产业和低碳经济等新业态为代表的第四次工业革命蓬勃发展，带动“稀散”元素矿产和“关键矿产”需求快速增长，全球资源需求的国家分布和品种结构发生重大变化。为满足不断增长和变化的矿产资源需求，新的地区、新的资源不断被发现，全球资源的分布和开发格局也正在发生新的变化，资源信息更加丰富和复杂多变。

为了向社会公众提供准确、可靠、及时的矿产资源信息，中国地质调查局 2020 年部署启动了全球矿产资源储量评估工作，计划用 5 年左右的时间，完成 40 种矿产全球储量动态评估，并向社会发布。

首批以锂、钴、镍、锡、钾盐 5 种战略性矿产为试点，初步建立了全球矿产资源信息调查和储量评估体系，全面采集了全球 3168 个矿山项目信息，对其中 987 个有查明资源储量的矿山项目，系统开展了储量评估，获得全新可靠的全球矿产资源储量数据。储量评估的基础是矿山项目数据采集全面准确，多渠道验证核实，尽可能做到大中型矿山不重不漏。本报告数据信息主要采自矿业公司年报、公司官网、协会评估报告、项目勘探报告、国

家矿业部门、研究报告和权威商业数据库，个别数据引用其他机构评估结果。对理论上未收集到的“遗漏”储量，建立了储量分布模型进行预测，数据纳入各矿种列表“其他”之中。

本项工作由中国地质调查局全球矿产资源战略研究中心牵头，中国地质调查局南京地质调查中心、成都地质调查中心、天津地质调查中心、西安地质调查中心、武汉地质调查中心、沈阳地质调查中心、发展研究中心，北京矿产地质研究院有限责任公司等单位共同参与完成。报告编审过程中得到了陈毓川院士、郑绵平院士、邵厥年、严铁雄、杨强、李剑、龚羽飞、王京彬、和志军、朱思才、唐长钟等储量管理和评估专家的大力帮助，在此一并感谢。报告不足之处，敬请批评指正。

目　录

锂（Li）

1. 锂矿资源类型及分布

全球锂矿类型有盐湖卤水型、伟晶岩型（包括相关的花岗岩及云英岩型）、黏土型、锂沸石型、油气田卤水型和地热卤水型，以盐湖卤水型和伟晶岩型锂矿最为重要。

全球锂资源丰富，但资源量分布很不均匀，主要集中在南美锂三角地区（阿根廷、玻利维亚和智利三国毗邻区域）、澳大利亚、中国、美国、刚果（金）和加拿大等国。盐湖卤水型锂矿主要分布在南美锂三角地区，是全球最重要的锂资源基地，其次是中国的青藏高原和美国西海岸。伟晶岩型锂矿全球分布广泛，主要分布在澳大利亚西部、中国青藏高原周边、刚果（金）等国家和地区，与造山带关系密切。黏土型锂矿主要分布在北美科迪勒拉地区，包括美国西部和墨西哥等地区。

目前全球锂矿开发主要集中在锂三角地区的智利和阿根廷，澳大利亚、加拿大、中国、美国，以及少数其他国家。总的来说，开发比较集中。其中智利、阿根廷和中国都是以盐湖卤水型锂矿开发为主，而澳大利亚和加拿大则以开发硬岩型锂矿为主。

2. 储量及资源量

（1）储量

截至 2020 年底，全球锂矿项目在录 376 个，其中 60 个有储量数据，分布在 18 个国家（图 1-1）。评估全球锂矿储量 12828 万吨（碳酸锂当量，下同），主要分布在智利 41.06%、澳大利亚 14.34%、阿

图 1-1 全球锂矿高级项目及主要国家储量分布（2020 年，储量：碳酸锂当量，吨）

Fig. 1-1 Advanced projects and major countries with lithium reserves in the world (2020, reserves: metric tons of Li_2CO_3 equivalent)

根廷 13.20%等国（表 1-1）。中国锂矿储量 810 万吨，占全球 6.31%。

表 1-1 全球锂矿（碳酸锂）储量主要分布国家（2020 年）
Table 1-1 Major countries with lithium (Li_2CO_3) reserves in the world (2020)

排名	国别		储量（万吨）	全球占比
1	智利	Chile	5,267	41.06%
2	澳大利亚	Australia	1,839[1]	14.34%
3	阿根廷	Argentina	1,693[2]	13.20%
4	中国	China	810	6.31%
5	美国	USA	570	4.44%
6	加拿大	Canada	369[2]	2.88%
7	刚果（金）	Congo(DRC)	363	2.83%
8	津巴布韦	Zimbabwe	243	1.89%
9	墨西哥	Mexico	173	1.35%
10	西班牙	Spain	79[2]	0.62%
11	其他	Others	1,422	11.09%
	合计	Total	12,828	100.00%

注：1-澳大利亚官方公布的 2020 年度储量是 2000 万吨；2-这些储量数据中包含有从高级资源量转换成的储量。

（2）资源量

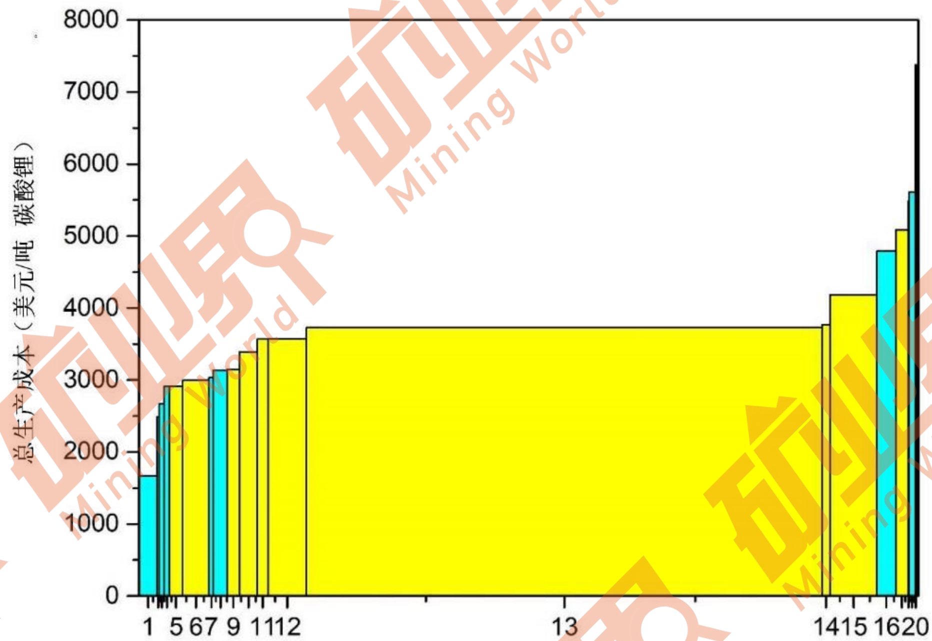
截至 2020 年底，全球锂矿项目在录 376 个，其中 110 个有资源量数据，分布在 20 个国家。评估全球锂矿资源量 34943 万吨，主要分布在玻利维亚 31.98%、阿根廷 22.71%、美国 15.72%和澳大利亚 5.90%。加拿大、捷克、智利等国也有分布，详见表 1-2。中国锂矿资源量 1914 万吨，占全球 5.48%。

3. 储量经济性概况

对全球 20 个锂矿项目储量的吨位—成本进行分析，成本区间 1600-7400 美元/吨（折碳酸锂/吨，下同），大致均值 3650 美元/吨（图 1-2）。硬岩锂的总生产成本变化较大，成本区间在 1600-7400 美元/吨之间，大致均值 3100 美元/吨。总体上，储量规模较大的矿山总生

表 1-2 全球锂矿（碳酸锂）资源量主要分布国家（2020 年）
Table 1-2 Major countries with lithium (Li_2CO_3) resources in the world (2020)

排名	国家		资源量（万吨）	全球占比
1	玻利维亚	Bolivia	11, 176	31. 98%
2	阿根廷	Argentina	7, 934	22. 71%
3	美国	USA	5, 492	15. 72%
4	澳大利亚	Australia	2, 062	5. 90%
5	中国	China	1, 914	5. 48%
6	刚果（金）	Congo (DRC)	1, 628	4. 66%
7	加拿大	Canada	1, 462	4. 18%
8	捷克	Czech	656	1. 88%
9	塞尔维亚	Serbia	617	1. 77%
10	智利	Chile	580	1. 66%
11	其他	Others	1, 422	4. 07%
	合计	Total	34, 943	100. 00%



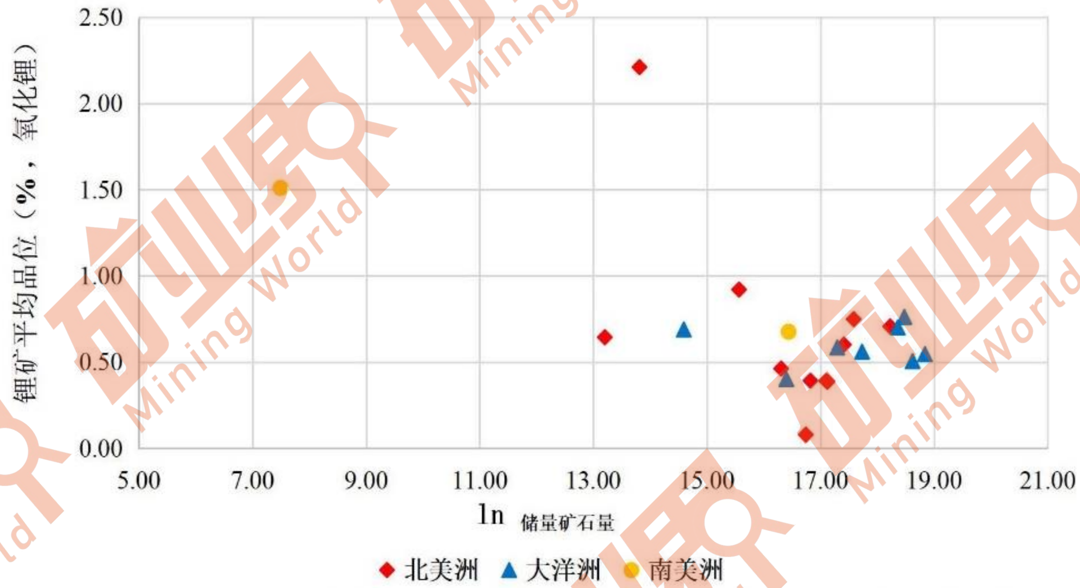
储量金属量（万吨）（黄色：盐湖锂，蓝色：硬岩锂）

注：横坐标柱子宽度代表矿石量规模，数字为各项目序号纵坐标为平均到每吨碳酸锂的总生产成本

图 1-2 全球锂矿吨位-成本模型图
Fig. 1-2 Reserve tonnage vs. cost model of lithium mines in the world

产成本较低。盐湖锂的总生产成本比较稳定，在 2900-4200 美元/吨，仅有一个矿山项目总生产成本为 5088 美元/吨，大致均值 3550 美元/吨。盐湖锂的储量规模和总生产成本的关系不是特别明显。与硬岩锂相比，盐湖锂的储量规模相对更大，总生产成本处于硬岩锂总生产成本最高值与最低值之间（如果分摊钾盐等共伴生组分的成本，盐湖锂成本可能显著降低）。上述锂矿总生产成本为项目总生产成本，包括项目中其他共伴生元素的生产成本。

对 34 个锂矿项目吨位—品位模型进行分析，全球大部分硬岩锂矿项目的储量平均品位在 0.4%-1.0%（金属锂，下同）之间，储量的矿石量规模在 1798 万吨至 1.5 亿吨之间（图 1-3）。从区域上看，分布在北美洲和大洋洲的锂矿较多。北美洲的硬岩锂矿项目品位大部分分布在 0.4%-1.0%之间，储量规模在 3.5 万吨-8247 万吨之间；大洋洲的硬岩锂矿项目品位分布在 0.4%-0.8%之间，分布较为集中，储量的矿石量规模为 218 万吨-1.5 亿吨之间。南美洲硬岩锂矿项目分布较



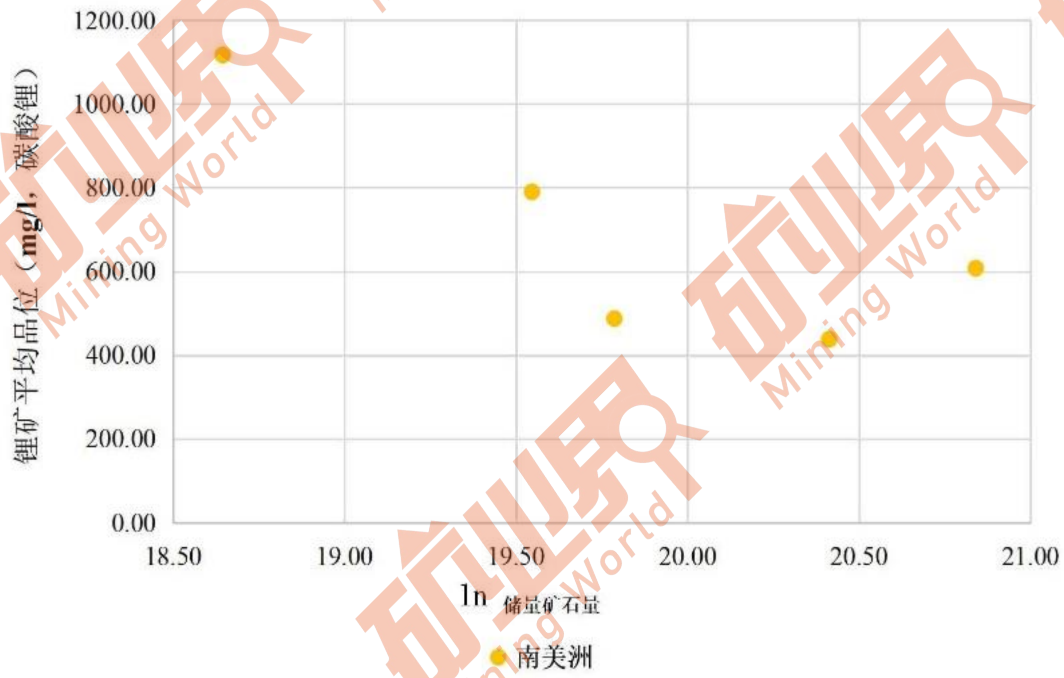
注：$\ln_{储量矿石量}$ 为锂矿储量矿石量以e为底的对数值，纵坐标为锂矿储量平均品位

图 1-3 全球硬岩锂矿储量吨位-品位模型图

Fig. 1-3 Reserve tonnage vs. grade model of hard rock type lithium deposits in the world

少，且储量规模和品位分布不均匀，规模较大的项目品位相对较低，品位较高的项目规模相对较小。

盐湖锂品位分布在 400 毫克/升—1200 毫克/升（金属锂，下同）之间（图 1-4），其储量的矿石量（卤水量）规模在 1.2 亿立方米-11 亿立方米之间。总体趋势上，规模较大的项目锂矿品位相对较低，反之亦然。



ln 储量矿石量 为锂矿储量矿石量以 e 为底的对数值，纵坐标为锂矿储量平均品位

图 1-4 全球盐湖锂矿储量吨位-品位模型图

Fig. 1-4 Reserve tonnage vs. grade model of salt lake type lithium deposits in the world

4. 锂资源潜力

盐湖卤水型锂矿主要分布在南美锂三角、中国青藏高原和美国西部，由于这些地区都为高山深盆地形，环境多较为恶劣，还有大量的盐湖尚未进行系统勘探，因此锂资源潜力很大。

伟晶岩型锂矿全球分布广泛，在各地史时期的造山带中均有分布，在全球具有很大的找矿潜力。例如努里斯坦—帕米尔高原中部地区，即阿富汗中西部，为全球最大的伟晶岩型锂矿资源潜力区，根据美国的相关报道，该区资源潜力巨大，甚至已有“阿拉伯的锂”的说法。

除此之外，非洲各稳定克拉通（如刚果克拉通）、南美圭亚那地盾等地区也是十分重要的伟晶岩型锂矿潜力区。

美国西部地区黏土型锂矿的资源潜力也很大，克莱顿谷(Clayton Valley)地区、大桑迪(Big Sandy)地区、布罗克里克(Burro Creek)地区和塔克帕斯(Thacker Pass)地区均有巨厚的含锂黏土层分布，合计有千万吨级的资源潜力。墨西哥西部和美国交界地区亦是黏土型锂矿的潜在区域，具有良好的资源前景。

钴（Co）

1. 钴矿资源类型及分布

全球钴矿主要有三种类型:（1）沉积岩型 Cu-Co 矿;（2）红土型 Ni-Co 矿和（3）岩浆型 Ni-Cu(-Co-PGE)矿。其它类型还有（4）黑色页岩赋矿型 Ni-Cu-Zn-Co 矿;（5）矽卡岩型 Fe-Cu-Co 矿;（6）铁氧化物型（IOCG 型）Cu-Au(-Ag-U-REE-Co-Ni)矿;（7）变质沉积岩赋矿型 Co-Cu-Au 矿;（8）密西西比河谷型 Pb-Zn(-Co-Ni)矿;（9）脉状热液交代型多金属富 Co 矿;（10）火山块状硫化物型 Cu-(Zn-Co-Ag-Au)矿和（11）海底富 Co 的 Fe-Mn 结核和结壳。

全球钴资源相对稀少，绝大部分为伴生矿床。从总资源量上看，主要分布于刚果（金）、印度尼西亚、澳大利亚、加拿大、菲律宾、赞比亚、新喀里多尼亚等国家。钴资源量分布呈现高度集中的特征，刚果（金）作为全球最重要的钴资源分布地区，其南部的中非铜钴成矿带集中了全球近一半的钴矿资源。

沉积岩型钴矿的开发主要集中在刚果（金），其次是赞比亚；红土型钴矿的开发主要集中在赤道附近国家，作为镍的伴生矿产开发，如澳大利亚、印度尼西亚等国；岩浆型钴矿的开发全球分布较广，如澳大利亚、加拿大、俄罗斯等国，作为伴生矿产回收。

2. 储量及资源量

（1）储量

截至 2020 年底，全球钴矿项目在录 1202 个，其中 59 个有储量数据，分布在 20 个国家（图 2-1）。评估全球钴矿储量 668 万吨，主

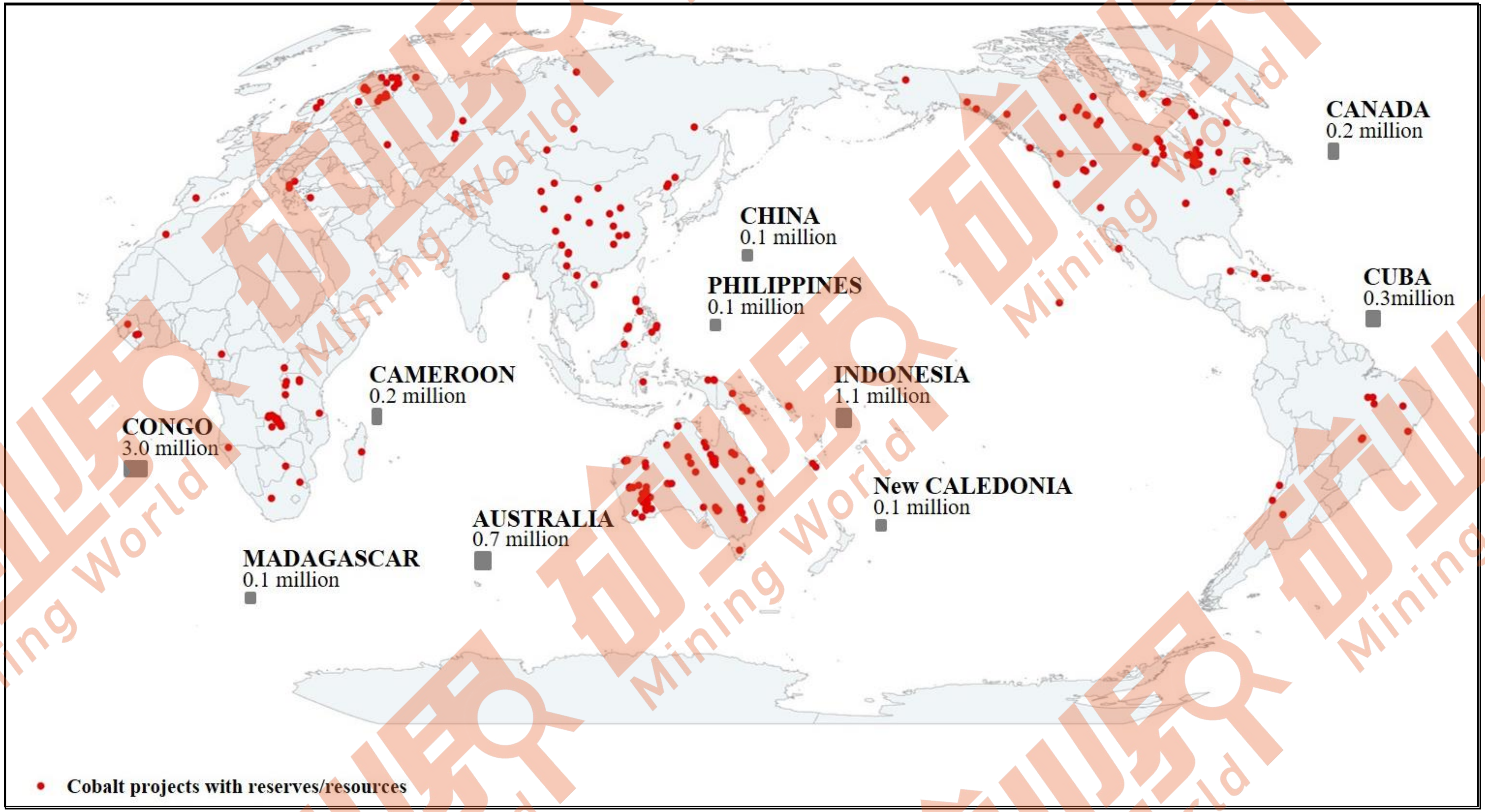


图 2-1 全球钴矿高级项目及主要国家储量分布（2020 年，储量：钴金属量，吨）

Fig. 2-1 Advanced projects and major countries with cobalt reserves in the world (2020, reserves: metric tons of cobalt metal)

要分布在刚果（金）44.46%，其次是印度尼西亚 16.02%、澳大利亚 9.73%，其他国家少量分布，详见表 2-1。中国钴矿储量 13 万吨，占全球 1.95%。沉积岩型钴矿是最主要的钴矿类型，储量占比约 50.53%，其次为红土型钴矿占比 40.02%，岩浆型钴矿占比 7.01%。

表 2-1 全球钴矿储量主要分布国家（2020 年）
Table 2-1 Major countries with cobalt reserves in the world (2020)

排名	国家		储量（万吨）	全球占比
1	刚果（金）	Congo(DRC)	297[1]	44.46%
2	印度尼西亚	Indonisia	107[2]	16.02%
3	澳大利亚	Australia	65[3]	9.73%
4	古巴	Cuba	25	3.74%
5	加拿大	Canada	19	2.84%
6	喀麦隆	Cameroon	18	2.69%
7	中国	China	13	1.95%
8	新喀里多尼亚	New Caledonia	12	1.80%
9	菲律宾	The Philippines	10	1.50%
10	马达加斯加	Madagascar	10	1.50%
11	其他	Others	92	13.77%
	合计	Total	668	100.00%

注：1-该储量数据中含有从高级资源量转换成储量的钴金属量 53 万吨。2-引自印度尼西亚官方公布的 2019 年度数据（该报告收集到的印度尼西亚红土镍矿项目伴生钴资源储量数据披露不全，故引用印度尼西亚官方数据）；3-澳大利亚官方公布的 2020 年度储量是 56 万吨。

（2）资源量

截至 2020 年底，全球 1202 个在录钴矿项目，其中 268 个有资源量数据，分布在 38 个国家。评估全球钴矿资源量 2344 万吨，刚果（金）资源量最多 35.24%、印度尼西亚 17.70%、澳大利亚 7.30%、汤加 6.48% 和加拿大 4.78%，其他国家少量分布，详见表 2-2。中国钴资源量 44 万吨，占全球 1.88%。

3. 储量经济性概况

对全球 20 个钴矿项目储量的吨位—成本进行分析（吨矿石中钴的矿山成本，下同），分摊的钴矿成本区间在 2.52-148.18 美元/吨之间

表 2-2 全球钴矿资源量主要分布国家（2020 年）

Table 2-2 Major countries with cobalt resources in the world (2020)

排名	国家		资源量（万吨）	全球占比
1	刚果（金）	Congo(DRC)	826	35.24%
2	印度尼西亚	Indonisia	415[1]	17.70%
3	澳大利亚	Australia	171	7.30%
4	汤加	Tonga	152	6.48%
5	加拿大	Canada	112	4.78%
6	菲律宾	The Philippines	97	4.14%
7	古巴	Cuba	85	3.63%
8	赞比亚	Zambia	68	2.90%
9	新喀里多尼亚	New Caledonia	49	2.09%
10	美国	USA	48	2.05%
11	中国	China	44	1.88%
12	巴西	Brazil	35	1.49%
13	巴布亚新几内亚	Papua New	33	1.41%
14	科特迪瓦	Côte d'Ivoire	29	1.24%
15	坦桑尼亚	Tanzania	23	0.98%
16	马来西亚	Malaysia	19	0.81%
17	俄罗斯	Russia	17	0.73%
18	墨西哥	Mexico	16	0.68%
19	其他	Others	105	4.48%
	合计	Total	2,344	100.00%

注：1-引自印度尼西亚官方公布的 2019 年度数据（该报告收集到的印度尼西亚红土镍矿项目伴生钴资源量数据披露不全，故引用印度尼西亚官方数据）。

（图 2-2）。总体来看，储量规模与分摊的生产成本之间有一定关联性，储量规模大的矿山生产成本相对较低。

从区域上看，各大洲的钴矿分摊生产成本也有明显差异性。欧洲、亚洲和北美洲钴矿的分摊生产成本最低，大致在 1.94-37.30 美元/吨之间。大洋洲钴矿的分摊生产成本总体在 30-50 美元/吨之间。非洲钴矿总生产成本分化现象明显，其生产成本呈现三个梯队：第一梯队的钴

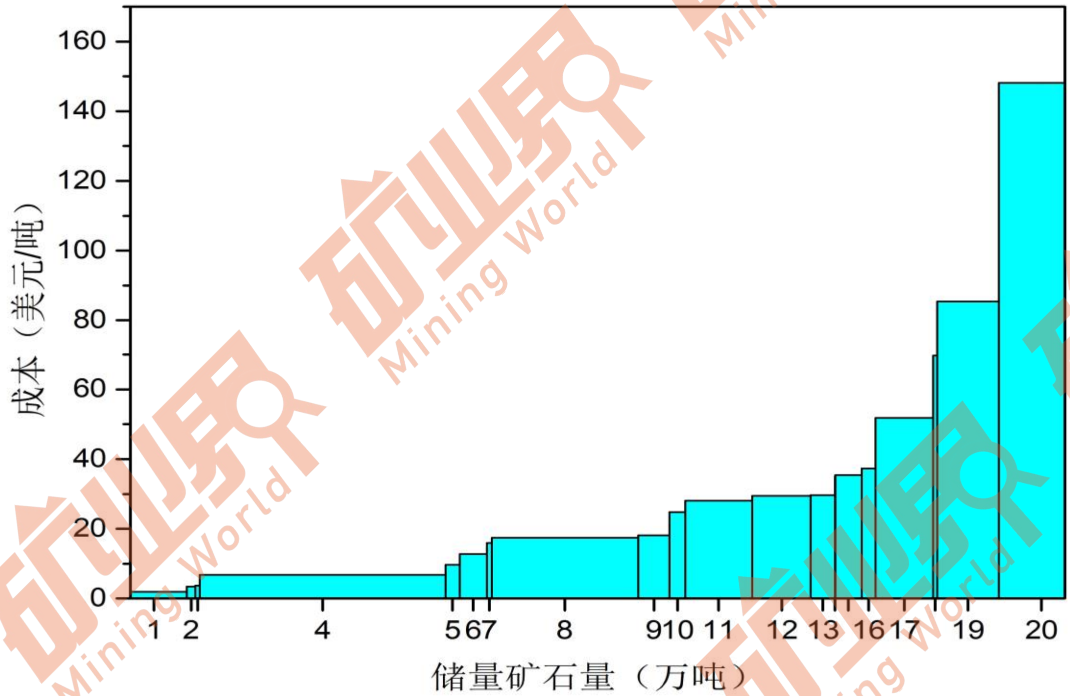


图 2-2 全球钴矿吨位-成本模型图
Fig. 2-2 Reserve tonnage vs. cost model of cobalt mines in the world

矿储量规模相对较小，钴矿分摊生产成本在 30 美元/吨以下；第二梯队的钴矿分摊生产成本在 70-100 美元/吨之间；第三梯队钴矿储量规模较大，钴矿分摊生产成本在 150 美元左右。考虑到钴矿整体的储量数据和成本数据较少，此分析结果仅供参考。虽然模型中欧洲钴矿的成本较低，但考虑模型中项目数量少，使用时应谨慎。

对 43 个钴矿项目吨位—品位模型分析(图 2-3)，北美洲、大洋洲、欧洲、亚洲大部分钴矿储量平均品位在 0.01% -0.15%之间，矿石储量规模变化较大，50 万吨至 3 亿吨之间均有分布。非洲钴矿项目平均品位较高，平均品位在 0.2%-0.8%之间，矿石储量规模在 500 万-1.8 亿吨之间，反映非洲的钴矿资源条件较好。

4. 钴资源潜力

非洲中部铜钴成矿带西段是目前全球钴资源分布最集中的地区，近年来不断有矿业项目投资投产，是最有潜力的钴资源潜力地区。澳

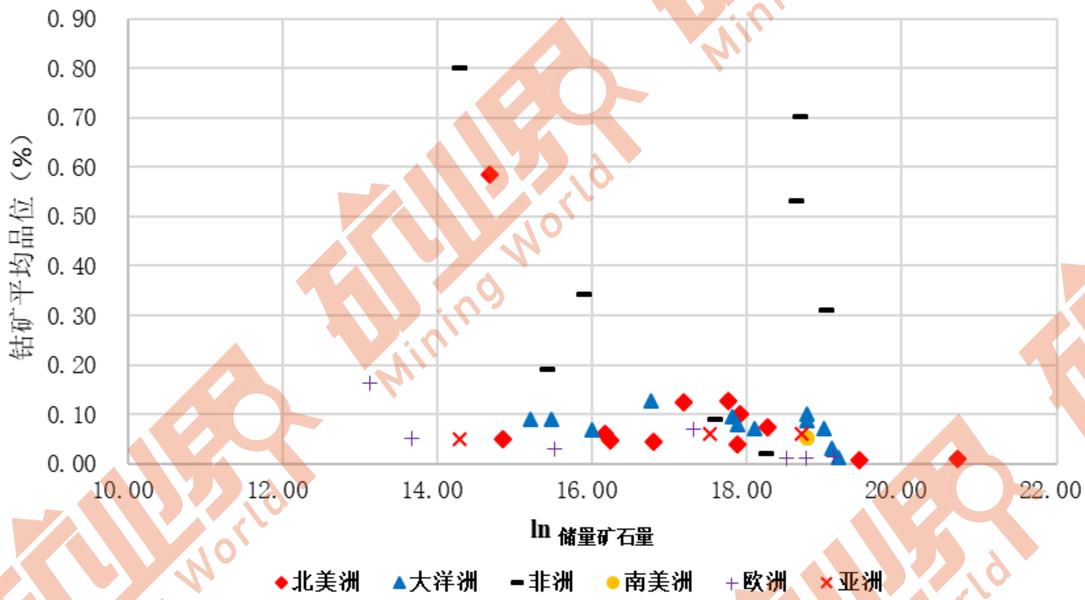


图 2-3 全球钴矿储量吨位-品位模型图

Fig. 2-3 Reserve tonnage vs. grade model of cobalt deposits in the world

大利亚西部和印度尼西亚等近赤道国家近年来也有大量红土型镍钴矿项目在建，也是极具潜力的钴资源地区。另外，海底 Fe-Mn-Co 结核和结壳是未来开发的重要潜在资源。

镍（Ni）

1. 镍矿资源类型及分布

全球镍矿主要有硫化物型、红土型和海底多金属结核/结壳三种类型，目前开发的为硫化物型和红土型。

全球镍矿资源丰富，分布较为广泛，主要分布在印度尼西亚、澳大利亚、俄罗斯、古巴、巴西、菲律宾、新喀里多尼亚、加拿大和中国等国家，其中红土型镍矿主要分布于印度尼西亚、澳大利亚、菲律宾、古巴、巴西、新喀里多尼亚、巴布亚新几内亚等国；硫化物型镍矿主要分布于南非、加拿大、俄罗斯、澳大利亚、中国等国家。目前全球镍矿开发主要集中在上述国家。

2. 储量及资源量

（1）储量

截至 2020 年底，全球镍矿项目在录 1153 个，其中 176 个有储量数据，分布在 26 个国家（图 3-1）。评估全球镍矿储量 9063 万吨（表 3-1），主要分布在印度尼西亚、澳大利亚、俄罗斯、古巴、巴西、加拿大和菲律宾等国家。其中红土型镍矿储量 5740 万吨，占全球总储量的 63%；硫化镍型储量 3318 万吨，占全球总储量的 37%。中国镍储量 398 万吨，占全球 4.39%。

（2）资源量

截至 2020 年底，全球镍矿项目在录 1153 个，其中 391 个项目有资源量数据，分布在 37 个国家。评估全球镍矿资源量 2.61 亿吨，主要集中在印度尼西亚、澳大利亚、俄罗斯、加拿大、巴西、新喀里多

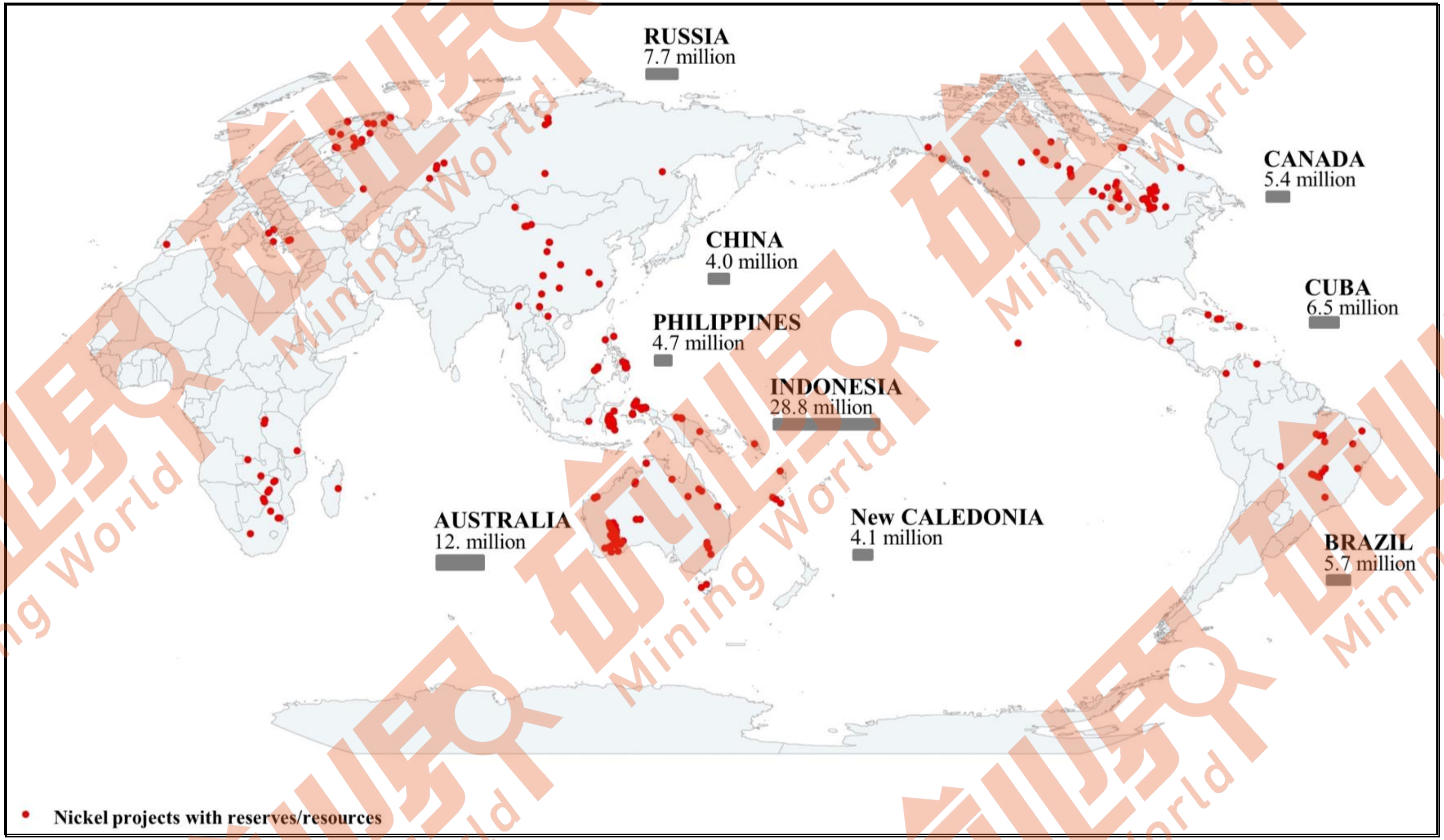


图 3-1 全球镍矿高级项目及主要国家储量分布（2020 年，储量：镍金属量，吨）

Fig. 3-1 Advanced projects and major countries with niekel reserves in the world (2020, reserves: metric tons of nickel metal)

表 3-1 全球镍储量主要分布国家（2020 年）
Table 3-1 Major countries with niekel reserves in the world (2020)

	国家		储量（万吨）	全球占比
1	印度尼西亚	Indonisia	2,875[1]	31.72%
2	澳大利亚	Australia	1,265[2]	13.96%
3	俄罗斯	Russia	770[3]	8.50%
4	古巴	Cuba	647	7.14%
5	巴西	Brazil	567	6.26%
6	加拿大	Canada	542	5.98%
7	菲律宾	The Philippines	472	5.21%
8	新喀里多尼亚	New Caledonia	409	4.51%
9	中国	China	398	4.39%
10	南非	South Africa	154	1.70%
11	危地马拉	Guatemala	98	1.08%
12	多米尼加	Dominica	93	1.03%
13	马达加斯加	Madagascar	79	0.87%
14	其他	Others	694	7.66%
	合计	Total	9,063	100.00%

注：1-印度尼西亚官方公布的 2019 年度镍储量为 7199 万吨；2-澳大利亚官方公布的 2020 年度储量是 830 万吨；3-俄罗斯官方 2020 年公布的镍矿储量是 800 万吨。

尼亚、菲律宾等国（表 3-2）。中国镍矿资源量 410 万吨，占全球 1.57%。

3. 储量经济性概况

对 39 个镍矿项目储量的吨位—成本分析（吨矿石中镍的矿山成本，下同），成本区间在 15-360 美元/吨之间（图 3-2），大致均值 130 美元/吨。总体看，储量规模与总生产成本之间有很强关联性，储量规模大的矿山总生产成本比储量规模小的成本低。上述镍矿总生产成本为项目总生产成本，包括项目中其他共伴生元素的生产成本。

从区域上看，各大洲镍矿总生产成本有明显差异。非洲、亚洲、欧洲的镍矿总生产成本较低，大部分矿山在 150 美元/吨以下。大洋

表 3-2 全球镍矿资源量主要分布国家（2020 年）
Table 3-2 Major countries with niekel resources in the world (2020)

排名	国家		资源量（万吨）	全球占比
1	印度尼西亚	Indonisia	6,071[1]	23.28%
2	澳大利亚	Australia	4,702	18.03%
3	俄罗斯	Russia	2,567	9.84%
4	加拿大	Canada	2,309	8.85%
5	巴西	Brazil	1,655	6.35%
6	新喀里多尼亚	New Caledonia	1,447	5.55%
7	菲律宾	The Philippines	1,432	5.49%
8	古巴	Cuba	1,388	5.32%
9	汤加	Tonga	979	3.75%
10	南非	South Africa	467	1.79%
11	中国	China	410	1.57%
12	坦桑尼亚	Tanzania	366	1.40%
13	所罗门群岛	Solomon Islands	329	1.26%
14	巴布亚新几内亚	Papua New Guinea	260	1.00%
15	布隆迪	Burundi	242	0.93%
16	哥伦比亚	Columbia	219	0.84%
17	希腊	Greece	212	0.81%
18	危地马拉	Guatemala	147	0.56%
19	瑞典	Sweden	126	0.48%
20	阿尔巴尼亚	Albania	96	0.37%
21	马达加斯加	Madagascar	93	0.36%
22	博茨瓦纳	Botswana	70	0.27%
23	其他	Others	495	1.90%
	合计	Total	26,082	100.00%

注：1-印度尼西亚官方公布的 2019 年度该国镍资源量为 16693 万吨。

洲的多数矿山总生产成本较高，在 150-300 美元/吨之间。南美洲的总生产成本介于中间，主要在 150-225 美元/吨之间。北美洲矿山的总生产成本出现很大分化，一部分矿山的储量规模大，生产成本在 50-150

美元/吨之间，另外一部分矿山储量规模小，生产成本在 225-350 美元/吨之间。

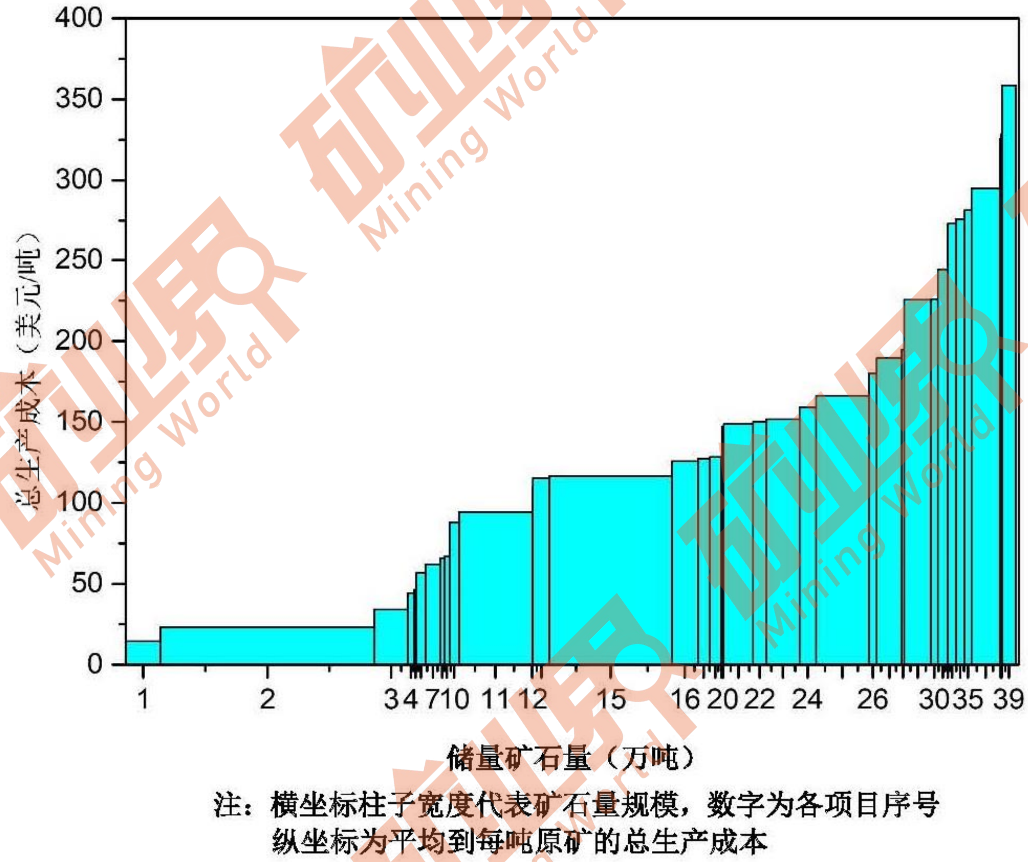
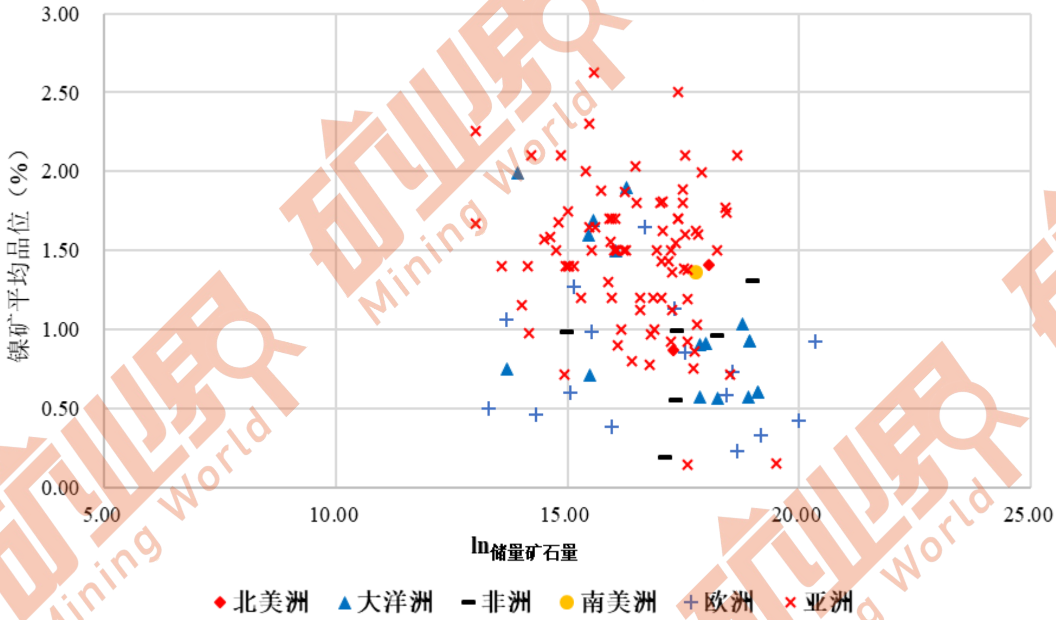


图 3-2 全球镍矿吨位-成本模型图
Fig. 3-2 Reserve tonnage vs. cost model of nickel mines in the world

从矿床类型角度分析，与层状镁铁质-超镁铁质侵入岩有关的硫化物型矿床的总生产成本相对较低，多数在 65 美元/吨以下。红土型矿床的总生产成本跨度较大，大部分在 50-250 美元/吨之间，个别矿山成本接近 300 美元/吨。其他与岩浆岩有关的硫化物型镍矿的总生产成本也出现较大跨度，一部分矿山的生产成本在 100-150 美元/吨之间，另一部分矿山在 250-350 美元/吨之间。

对 127 个镍矿项目吨位—品位模型分析，品位区间 0.2%-2.6%，大部分镍矿项目储量的平均品位在 0.5%-2.0%之间，大致均值 1.2%；全球镍矿储量（矿石量，下同）规模在 300 万吨至 6.8 亿吨之间（图

3-3）。总的来看，吨位和品位之间并没有很好的关联性。



注：ln储量矿石量 为镍矿储量矿石量以e为底的对数值，纵坐标为镍矿储量平均品位

图 3-3 全球镍矿储量吨位-品位模型图（矿石量）

Fig. 3-3 Reserve tonnage vs. grade model of nickel deposits in the world

从区域上看，亚洲的镍矿数量最多。亚洲镍矿项目的平均品位和储量规模均比较分散，平均品位在 0.5%-3.0%之间变化，储量规模在 45 万-3 亿吨之间变化。储量平均品位大于 2.0%的项目主要集中在亚洲，项目数量较少，项目储量规模大小不等。大洋洲和非洲的镍矿平均品位在 0.5%-1.5%之间，储量规模普遍较大。欧洲镍矿平均品位整体在 0.25%-1.5%之间，略偏低，储量规模大小不等。

4. 镍矿资源潜力

菲律宾南部和印度尼西亚北东部，尤其是苏拉威西岛，红土型镍矿的找矿潜力很大。南美和非洲东北部地区寻找与大火成岩省有关的铜镍硫化物矿床潜力较大。在造山带，碰撞造山后环境也有形成铜镍硫化物矿床的潜力（如中亚造山带）。大洋多金属结核/结壳中的镍资源潜力巨大，是未来镍资源勘查开发的重要潜在方向。

锡（Sn）

1. 锡矿资源类型及分布

锡矿床可分为斑岩型、云英岩型、矽卡岩型、石英脉型、锡石硫化物型以及砂锡矿等 6 种主要类型。砂锡矿为各类型的原生锡矿受改造后形成，形成时代多为新生代，主要见于亚洲东南部。

全球锡矿地域分布较广泛，但产出常以“区”或“带”的形式集聚出现。根据全球性锡矿集中产出的特点，可将锡矿划分为 3 个主要锡矿成矿带：环滨太平洋巨型锡矿成矿带、欧亚大陆内锡成矿带和中南部非洲锡成矿带。其中环滨太平洋巨型锡成矿带锡矿储量超过世界总储量的 80%，成矿时代以中、新生代为主。

锡矿开发主要集中在中国和东南亚国家（包括印度尼西亚、马来西亚）、南美的玻利维亚和中南部非洲等少数国家。

2. 储量及资源量

（1）储量

截至 2020 年底，全球锡矿项目在录 132 个，其中 27 个有储量数据，分布在 15 个国家（图 4-1）。评估全球锡矿储量 327 万吨，主要储量分布国家为中国 23.24%、俄罗斯 13.15%、巴西 12.84%、澳大利亚 11.93%、印度尼西亚 10.40%和马来西亚 7.65%（见表 4-1）。

（2）资源量

截至 2020 年底，全球锡矿项目在录 132 个，其中 52 个有资源量数据，分布在 18 个国家。评估全球锡矿资源量 807 万吨，主要分布在中国 41.88%、玻利维亚 10.16%、印度尼西亚 9.29%，其他国家锡

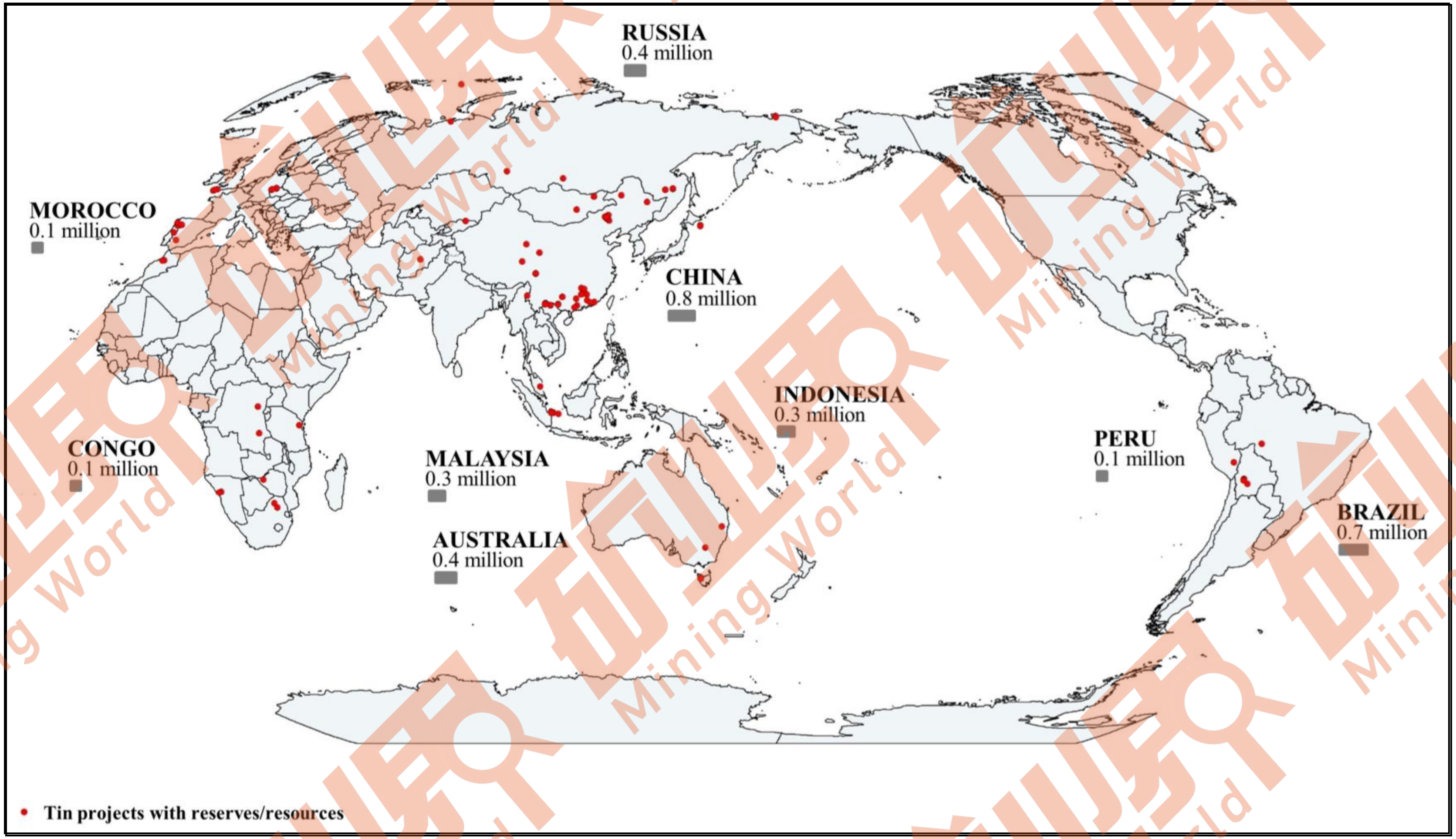


图 4-1 全球锡矿高级项目及主要国家储量分布（2020 年，储量：锡金属量，吨）

Fig. 4-1 Advanced projects and major countries with tin reserves in the world (2020, reserves: metric tons of tin metal)

表 4-1 全球锡矿储量主要分布国家（2020 年）
Table 4-1 Major countries with tin reserves in the world (2020)

排名	国家	储量（万吨）	全球占比
1	中国 China	76	23.24%
2	俄罗斯 Russia	43[1]	13.15%
3	巴西 Brazil	42[2]	12.84%
4	澳大利亚 Australia	39[3,4]	11.93%
5	印度尼西亚 Indonisia	34	10.40%
6	马来西亚 Malaysia	25[2]	7.65%
7	刚果（金） Congo(DRC)	14	4.28%
8	秘鲁 Peru	14	4.28%
9	摩洛哥 Morocco	6	1.83%
10	吉尔吉斯斯坦 Kyrgyzstan	2	0.61%
11	其他 Others	32	9.79%
	合计 Total	327	100.00%

注：1-俄罗斯官方 2020 年对内和对外公布的锡矿储量分别是 159 万吨和 20 万吨；2-引自美国地质调查局公布的 2020 年数据；3-该储量数据中含有从高级资源量转换成储量的锡金属量 24 万吨；4-澳大利亚官方公布的 2020 年度储量是 26 万吨。

资源量较少（表 4-2）。

3. 储量经济性概况

对全球 6 个锡矿项目储量的吨位—成本分析（吨矿石锡的矿山成本，下同），成本区间在 60-170 美元/吨，大致均值 100 美元/吨（图 4-2）。其中，规模较大的锡矿山，其总生产成本在 80 美元/吨以下。锡矿总生产成本为项目总生产成本，包括项目中其他共伴生元素的生产成本。

对 29 个锡矿项目的吨位—品位模型进行分析，品位区间 0.1%-4.2%，大部分锡矿项目储量的平均品位小于 1.0%，大致均值 0.4%（图 4-3）。除个别项目以外，南美洲和亚洲锡矿的品位均在 1.0%以下。储量矿石量规模在 10 万吨至 1.7 亿吨之间。从区域上看，分布在南美洲和亚洲的锡矿数量最多，其次为欧洲。从规模上看，亚洲

表 4-2 全球锡矿资源量主要分布国家（2020 年）
Table 4-2 Major countries with tin resources in the world (2020)

排名	国家		资源量（万吨）	全球占比
1	中国	China	338	41.88%
2	玻利维亚	Bolivia	82	10.16%
3	印度尼西亚	Indonisia	75	9.29%
4	俄罗斯	Russia	54[1]	6.69%
5	哈萨克斯坦	Kazakhstan	49	6.07%
6	澳大利亚	Australia	37	4.58%
7	捷克	Czech	28	3.47%
8	秘鲁	Peru	23	2.85%
9	刚果（金）	Congo(DRC)	22	2.73%
10	德国	Germany	22	2.73%
11	其他	Others	77	9.54%
	合计	Total	807	100.00%

1-俄罗斯官方 2020 年对内公布的锡矿资源量（C_2）为 53 万吨。

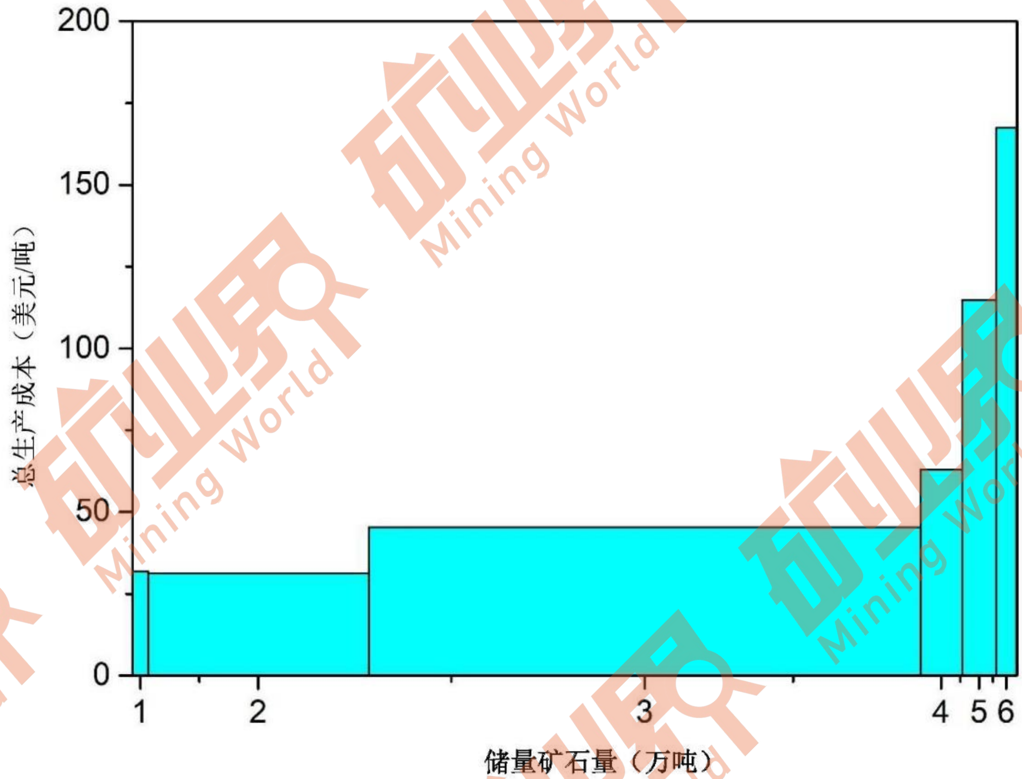
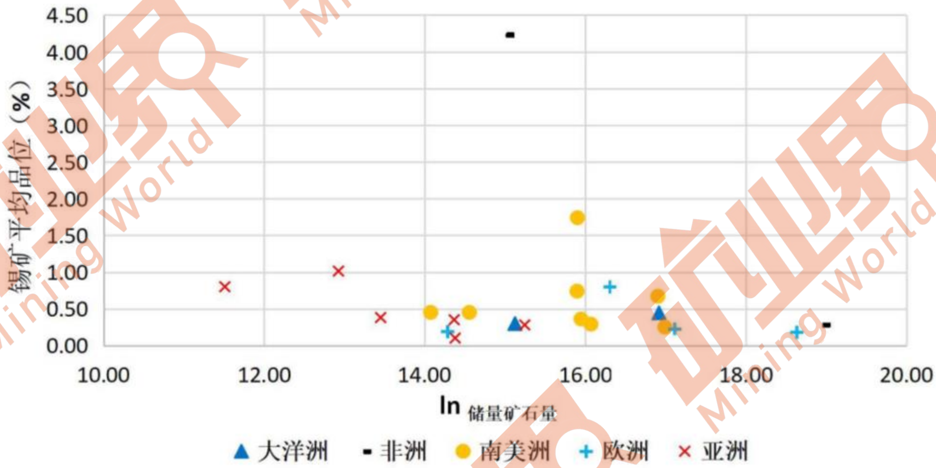


图 4-2 全球锡矿吨位-成本模型图
Fig. 4-2 Reserve tonnage vs. cost model of tin mines in the world

的锡矿储量矿石量较南美洲锡矿储量小，前者大部分在 10 万吨-418 万吨之间，后者储量规模在 585 万吨-1.5 亿吨。欧洲锡矿虽然数量少，品位也较一般，但是储量矿石量规模相对较大，为 130 万吨-2400 万吨之间。非洲的 Bisie 锡矿品位较高，为 4.23%，储量矿石量规模为 333 万吨。



注：ln储量矿石量 为锡矿储量矿石量以e为底的对数值，纵坐标为锡矿储量平均品位

图 4-3 全球锡矿储量吨位-品位模型图

Fig. 4-3 Reserve tonnage vs. grade model of tin deposits in the world

4. 锡资源潜力

原生锡矿主要与 S 型花岗岩或者高分异的 I 型花岗岩有关，根据已有的矿床发现和全球花岗岩的分布特征，认为全球锡资源的找矿潜力仍然较大，主要集中在东南亚、南美、特提斯成矿域中东段，以及欧洲的部分地区。在中国，除了在锡矿的主要集中区—华南地区仍然具有较大的找矿潜力，近些年来在大兴安岭中南段和藏南地区都有规模较大的锡矿发现，预示着这些地区具有较大的锡矿找矿潜力，能够补充因为不断开发而减少的锡储量。

钾盐（K）

1. 钾盐资源类型及分布

钾盐矿床可划分为沉积型、盐湖型（第四纪）和地下卤水型 3 个类型。其中沉积型钾盐矿床按其主要矿物成分特点，可进一步细分为氯化物型、硫酸盐型和混合型等 3 种类型。

全球钾盐资源极为丰富，但分布很不均衡。迄今为止，全球已发现的世界级钾盐盆地和超大型钾盐矿床主要分布在北美、欧洲、南美和亚洲等地区，其中以俄罗斯、加拿大、白俄罗斯等国最为丰富。全球钾盐的开发也主要集中在这些钾盐资源丰富的国家。

2. 储量及资源量

（1）储量

截至 2020 年底，全球钾盐项目在录 306 个，其中 48 个有储量数据，分布在 15 个国家（图 5-1）。评估全球钾盐储量 129 亿吨（氯化钾当量，下同），主要分布在俄罗斯 38.16%、加拿大 25.38%、白俄罗斯 10.03%、土库曼斯坦 7.61%，其他国家少量分布，详见表 5-1。中国钾盐储量 3.17 亿吨，占全球 2.46%。

（2）资源量

截至 2020 年底，全球在录钾盐项目 306 个，其中 51 个有资源量数据，分布在 17 个国家。评估全球钾盐资源量共 430 亿吨，主要集中在俄罗斯 48.79%和加拿大 34.78%，其他国家少量分布，详见表 5-2。中国钾盐资源量 4.3 亿吨，占全球 1.02%。

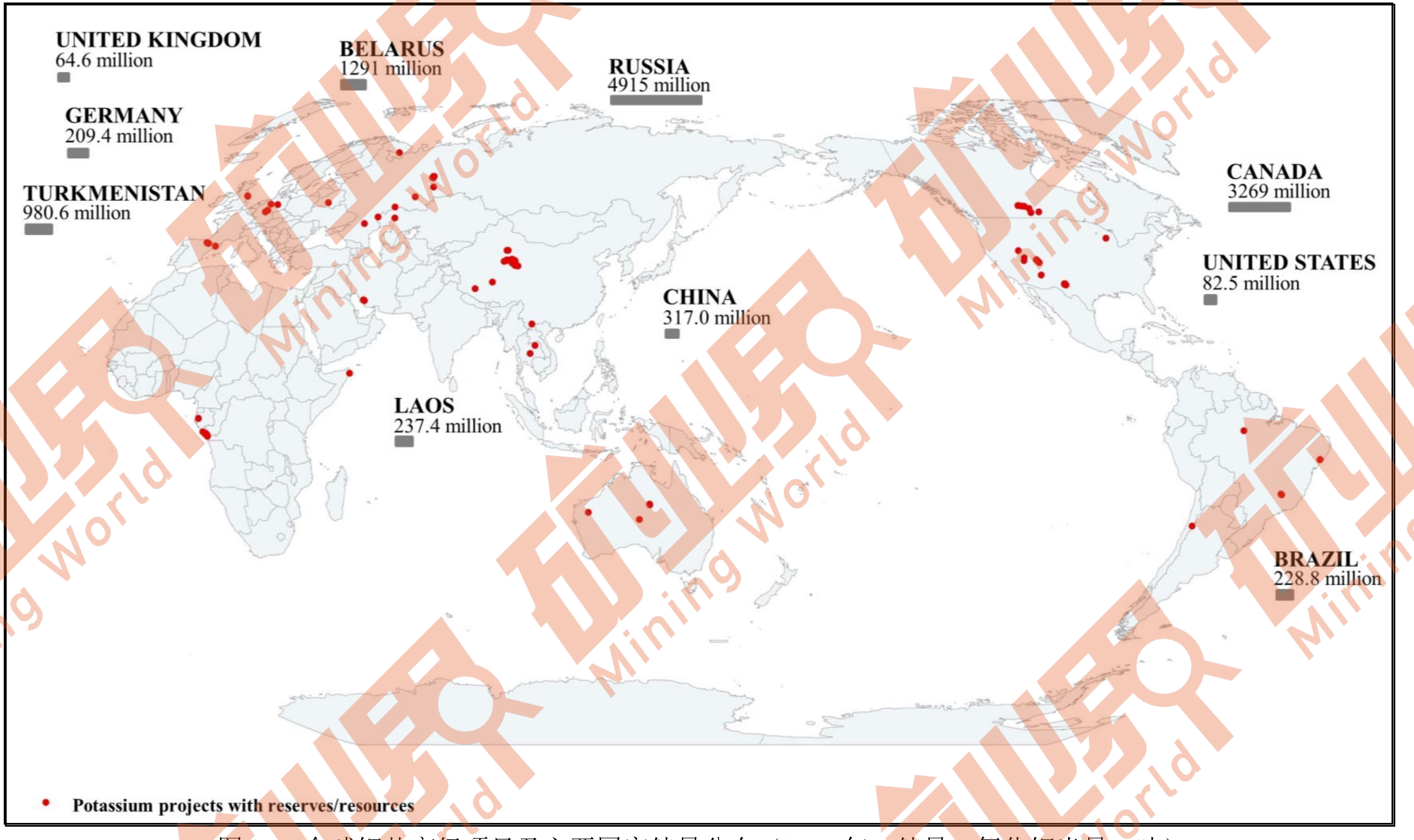


图 5-1 全球钾盐高级项目及主要国家储量分布（2020 年，储量：氯化钾当量，吨）

Fig. 5-1 Advanced projects and major countries with potash reserves in the world (2020, reserves: metric tons of KCl equivalent)

表 5-1 全球钾盐（氯化钾）储量主要分布国家（2020 年）
Table 5-1 Major countries with potash (KCl) reserves in the world (2020)

排名	国家		储量（万吨）	全球占比
1	俄罗斯	Russia	491,459[1]	38.16%
2	加拿大	Canada	326,910[2]	25.38%
3	白俄罗斯	Belarus	129,147	10.03%
4	土库曼斯坦	Turkmenistan	98,062[3]	7.61%
5	中国	China	31,700	2.46%
6	老挝	Laos	23,736	1.84%
7	巴西	Brazil	22,880	1.78%
8	德国	Germany	20,940	1.63%
9	美国	USA	8,248	0.64%
10	英国	UK	6,462	0.50%
11	其他	Others	128,395	9.97%
	总计	Total	1,287,939	100.00%

注：1-该储量数据中含有部分钾盐项目采用了前苏联的储量标准 A+B+C1 级总量，并未细分，但是考虑到这些矿山基本都是生产矿山，故将这些资源/储量数据均当作储量来处理，未单独扣除采矿损失和贫化。2020 年，俄罗斯官方对内和对外公布的钾盐(KCl)储量分别是 47.23 亿吨和 13.34 亿吨；2-该储量数据中含有从高级资源量转换成储量的氯化钾当量 15.28 亿吨；3-本储量数据来自 2005 年的一份考察报告数据，也是采用了前苏联的储量标准计算的井下开采法 A+B+C1 级总储量，未扣除矿山实际生产消耗的钾盐储量。地下溶解法 C1 级储量 2.78 亿吨氯化钾未包含在这个储量数据内。

3. 储量经济性概况

对全球 5 个钾盐项目储量的吨位—成本进行分析，成本区间在 7-99 美元/吨之间（吨矿石），大致均值 60 美元/吨之间（图 5-2）。钾盐矿伴生组分较少，总生产成本一般为钾盐单矿种的总生产成本。总体看，储量规模与总生产成本之间关联性不强。

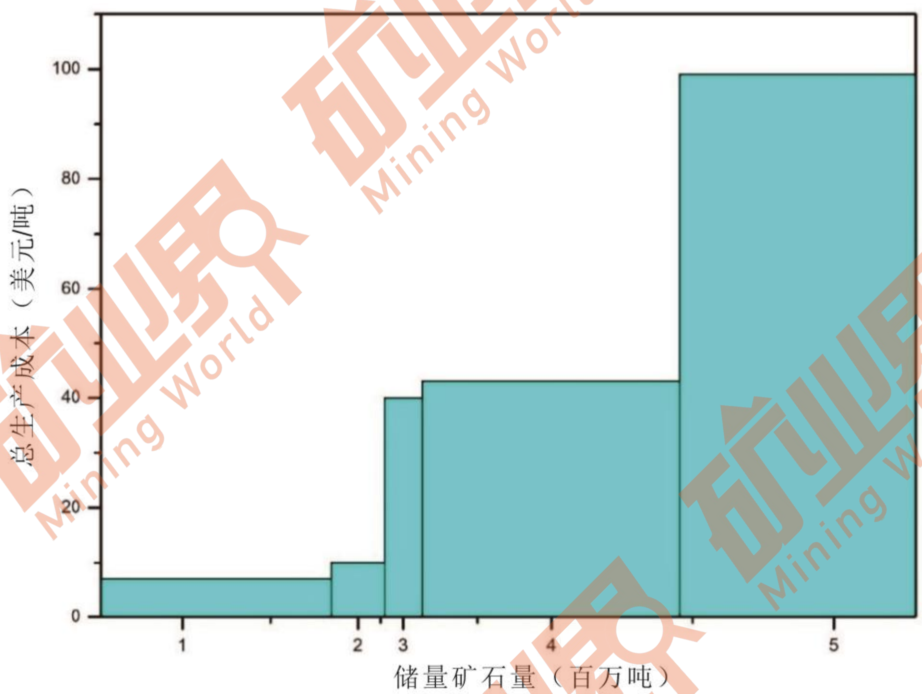
对 50 个钾盐项目吨位—品位模型进行分析，氯化钾品位区间 10%-50%，大致均值在 25%左右（图 5-3），矿石储量规模在 100 万吨至 100 多亿吨之间变化，总体上全球钾盐矿储量的平均品位和储量规模差异非常大。大洋洲、非洲、南美洲、亚洲达到储量阶段的钾盐

表 5-2 全球钾盐（氯化钾）资源量主要分布国家（2020 年）

Table 5-2 Major countries with potash (KCl) resources in the world (2020)

排名	国家		资源量（万吨）	全球占比
1	俄罗斯	Russia	2,096,691[1]	48.79%
2	加拿大	Canada	1,494,908	34.78%
3	哈萨克斯坦	Kazakhstan	162,920	3.79%
4	刚果（布）	Republic of the Congo	134,998	3.14%
5	德国	Germany	82,915	1.93%
6	美国	USA	67,356	1.57%
7	白俄罗斯	Belarus	71,889	1.67%
8	巴西	Brazil	47,224	1.10%
9	中国	China	43,660	1.02%
10	安哥拉	Angola	28,256	0.66%
11	其他	Others	66,838	1.56%
	总计	Total	4,297,655	100.00%

注：1-2020 年，俄罗斯政府部门对内公布的钾盐（KCl）资源量是 209.20 亿吨.



注：横坐标柱子宽度代表矿石量规模，数字为各项目序号
纵坐标为平均到每吨原矿的总生产成本

图 5-2 全球钾盐矿吨位-成本模型图

Fig. 5-2 Reserve tonnage vs. cost model of potash mines in the world

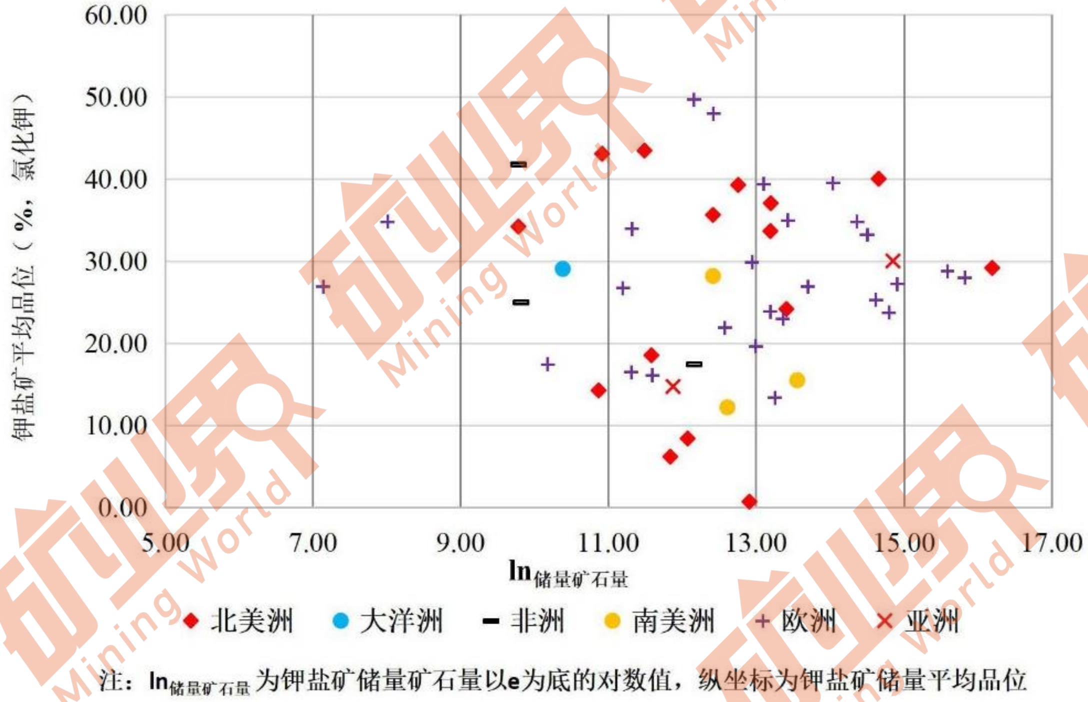


图 5-3 全球钾盐矿储量吨位-品位模型图

Fig. 5-3 Reserve tonnage vs. grade model of potash deposits in the world

矿项目数量较少，钾盐平均品位大多数在 10-30%之间，储量矿石量规模在 1800 万吨至 28 亿吨之间。

4. 钾盐资源潜力

"一带一路"地区横跨劳亚、特提斯和环太平洋成矿域，其沿线地区钾盐资源丰富，资源潜力巨大，主要成钾盆地有卡拉库姆盆地、滨里海盆地、呵叻—沙空那空盆地、万象—甘蒙盆地、达纳吉尔裂谷盆地、蔡希斯坦盆地、彼里皮亚特盆地、前乌拉尔边缘坳陷和柴达木盆地、罗布泊盆地等。另外刚果（布）西部的 Cotier（亦称海岸盆地）和加蓬 Gabon 盆地均发现钾盐沉积，其中刚果（布）Cotier 盆地推测氯化钾当量资源量在 100 亿吨以上。

附录

1. 术语解释

储量：探明矿产资源量中的经济可采部分。本报告使用如下：

（1） 以 CRIRSCO 分类规范为基础，采集的储量数据包括证实储量和可信储量；

（2） 个别矿山项目的高级别资源量，根据需要采用一定的评估方法，部分转换为储量；

（3） 中国矿产资源储量分类尚未完成从 GB/T17766-1999 标准向 GB/T 17766-2020 储量分类规范的转换，故本报告对原有标准下的最新资源储量数据，按照可利用性，进行储量评估而来。

资源量：通过一定工程控制的查明的矿产资源。本报告使用如下：

（1） 以 CRIRSCO 分类规范为基础，采集的资源量数据包括探明资源量、控制资源量和推断资源量，不包括预测资源量等潜在资源量；

（2） 中国资源量按照原规范中（333）及以上级别的资源量；

（3） **本报告中的储量和资源量互不包含，即资源量不包含储量。**

2. 数据来源

本报告统计的资源量/储量数据截止时间为 2020 年底。

从公司报告（含年报/储量报告、勘探报告、公司官网/内部报告）、商业数据库、政府或官网、文献等多渠道，全面收集了上述 5 种矿产全球 3168 个矿业项目（包括生产与停产的矿山、正在勘查的矿业项目，以及勘查工作已经完成，正在开展预可研或者可研阶段的矿业项目），努力保证大中型矿山项目不遗漏。采集的数据以公司报告和政府公布的数据为主。

在录得的 3168 个矿业项目中，有资源量/储量数据的项目 987 个，对其数据进行多方相互验证，保证数据的真实性、时效性，以及来源可追索更新。从理论上讲，不可能收集到全球所有矿业项目的储量数据，因此采用数理统计的方法，建立了储量分布模型，估算了未采集到的遗漏的储量占比。

3. 评估技术路线及特殊数据处理

（1）技术路线

多渠道数据采集（保证数据采集全面真实）——筛选核实（剔除异常，检验核实数据，保证数据可靠）——储量/资源量数据对标转化（不同储量体系数据对标转换）——部分资源量转换成储量——模型分析（通过储量分布数理模型推测未采集资源占比——汇总统计（储量的国家分布及成本品质分析等）。

（2）资源量转换储量的原则

针对部分实际已开采，但只公布了资源量的矿业项目，进行资源量转换为储量评估。资源量转换为储量时，需将各级别资源量相加后整体进行转换，转换后的“储量”类别，不再细分。对已实际开采的资源量进行经济评估，如果结果为经济可采，则进行储量转换，转换关系为：

储量= （Measured+Indicated）资源量*平均回采率 AERR

此处的平均回采率 AERR 是指模型中典型矿山的平均回采率。

资源量转换为储量后，在资源量类别中不能再对其重复统计，即最终的资源量中要扣除掉已经转换的资源量。

（3）特殊数据处理

针对部分在产矿山缺少储量数据的情况，采用了前面介绍的资源量转换储量的方法，将部分或者全部的高级别资源量转换成了储量，包括 12 个锂矿项目、5 个钴矿项目、1 个钾盐项目和 1 个锡矿项目。

另有 7 个钾盐项目，收集的资源/储量数据是采用前苏联储量标准的 A+B+C1 级总量，并未细分。考虑到这些矿山都是生产矿山，故将这些资源/储量数据均当作储量来处理。

印度尼西亚钴矿资源量和储量数据采用了印尼地调局官方公布数据，没有采用印尼各矿业项目的数据。

国内这 5 个矿种的储量和资源量数据是利用 2020 年度全国矿产资源储量通报的数据进行重新评估获得的。

全球锂、钴、镍、锡、钾盐

矿产资源储量评估报告（2021）

Assessment Report for Lithium, Cobalt, Nickel, Tin, and Potash Reserves in the World (2021)

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Assessment Report
for Lithium, Cobalt, Nickel, Tin, and Potash Reserves in the World (2021)

Research Center for Strategy of Global Mineral Resources,

China Geological Survey

October 2021

Preface

This is the first time that a Chinese research institute has independently assessed and published the information on global mineral reserves.

The global pattern of supply and demand for mineral resources has changed significantly in the 21st century. The demand for resources in developed Western countries tends to be saturated, while the demand for resources in newly industrialized countries is growing rapidly, and the focus of resource demand is shifting to the East. As the fourth industrial revolution, represented by new forms of flourishing businesses such as new energy, information industry and low-carbon economy, it drives the rapid demand growth of "dispersed elements" minerals and "key minerals", and leads to significant changes in the national distribution of global resource demand and mineral product composition. To meet the growing and changing demand for mineral resources, new areas and new resources are being discovered, and the global distribution and development pattern of mineral resources is undergoing new changes. The mineral resources information is becoming more abundant, complex, and variable.

In order to provide accurate, reliable and timely mineral resources information to the public, the China Geological Survey (CGS) deployed and launched the global mineral reserves assessment in 2020. It plans to complete the dynamic assessment of global reserves of 40 minerals in five years and release it to the society.

The first batch of five strategic minerals, i.e., lithium, cobalt, nickel, tin, and potash, was piloted, and a global mineral resources information survey and reserve assessment system was initially established. 3,168 mining projects around the world were comprehensively collected, of which 987 projects with identified reserves and/or resources were systematically evaluated to obtain new and reliable global mineral resources and reserves data. The basis of the reserve assessment is a comprehensive and accurate data collection of mining projects, with multiple channels of verification and validation, to ensure, no large or medium-sized mining projects are overlapped or omitted. The mineral information in this report is mainly taken from annual reports and websites of mining companies, assessment reports of associations, project exploration reports, national mining departments, research reports and authoritative commercial databases, while very few data are quoted from the assessment results of other institutions. For the “missing” reserves that have not been collected in theory, a reserve distribution model is established to predict them, which are included in the “Other” of reserve tables for each mineral.

This project was spearheaded by the Research Center for Strategy of Global Mineral Resources of CGS, together with the Nanjing Center of CGS, Chengdu Center of CGS, Tianjin Center of CGS, Xi'an Center of CGS, Wuhan Center of CGS, Shenyang Center of CGS, Development Research Center of CGS, and Beijing Institute of Geology for Mineral Resources Co., Ltd. If you find that the report has any shortcomings, please point out and correct them.

Lithium (Li)

1. Types and distribution of lithium resources

The characterization of Lithium deposits around the world based on their occurrence include: salt-lake brine type, pegmatite type (including granite- and greisen-related types), clay type, lithium zeolite type, oil and gas field brine type, and geothermal brine type, with the former two types being the most important ones. The salt-lake brine type and the pegmatite type are the most abundant types of lithium deposits in the world.

The world is rich in lithium resources; however, the distribution of lithium resources is very uneven, especially in the Lithium Triangle of South America (the adjacent areas of Argentina, Bolivia, and Chile), Australia, China, the United States, Congo (DRC), and Canada. The salt-lake brine type lithium deposits are mainly distributed in the Lithium Triangle of South America, which is the most important lithium resource base in the world, followed by the Qinghai-Tibet Plateau in China and the West Coast of the United States. Pegmatite type lithium deposits are widely distributed globally, predominantly in Western Australia, surrounding area of Qinghai-Tibet Plateau of China, and Congo (DRC). These types of deposits are closely related to orogenic belts. Clay type lithium deposits are commonly distributed in the Cordillera region of North America, including the western United States and Mexico.

Presently, the global lithium mining is mainly concentrated in Chile and Argentina in the Lithium Triangle, Australia, Canada, China, the United States, and a few other countries. Overall, the development of the lithium mine is relatively high, with the salt-lake brine type lithium mines mainly in Chile, Argentina, and China, while the hard rock type lithium mines mainly in Australia and Canada.

2. Reserves and resources

(1) Reserves

By the end of 2020, 376 lithium mining projects were recorded worldwide. Reserves data are included in 60 lithium mining projects, which are distributed in 18 countries (Fig. 1-1). Estimated global lithium reserves are 128.28 million tons (equivalent to lithium carbonate as shown below), mainly distributed in Chile (41.06%), Australia (14.34%), and Argentina (13.20%) (Table 1-1). 8.1 million tons of lithium reserves are recorded in China, accounting for 6.31% of the world's lithium reserves.

(2) Resources

By the end of 2020, 376 lithium mining projects were recorded in the world, of which 110 lithium projects distributed in 20 countries, were reported resources data. The global lithium resources are estimated to be 349.43 million tons, mainly distributed in Bolivia (31.98%), Argentina (22.71%), the United States (15.72%), and Australia (5.90%). There are also distributions in Canada, Czech Republic, and Chile (Table 1-2). The lithium resources are 19.14 million tons in China, accounting for 5.48% of the world's lithium resource.

3. Overview of reserve economy

The cost range is US$1600-7400/ton (equivalent to lithium carbonate/ton, as shown below) based on analyzing the tonnage-cost of the reserves of 20 lithium mining projects in the world, with the average cost of roughly US$3650/ton (Fig. 1-2). The total production cost of hard rock lithium varies greatly, and the cost range is between

Fig. 1-1 Advanced projects and major countries with lithium reserves in the world (2020, reserves: metric tons of Li_2CO_3 equivalent)

Table 1-1 Major countries with lithium (Li_2CO_3) reserves in the world (2020)

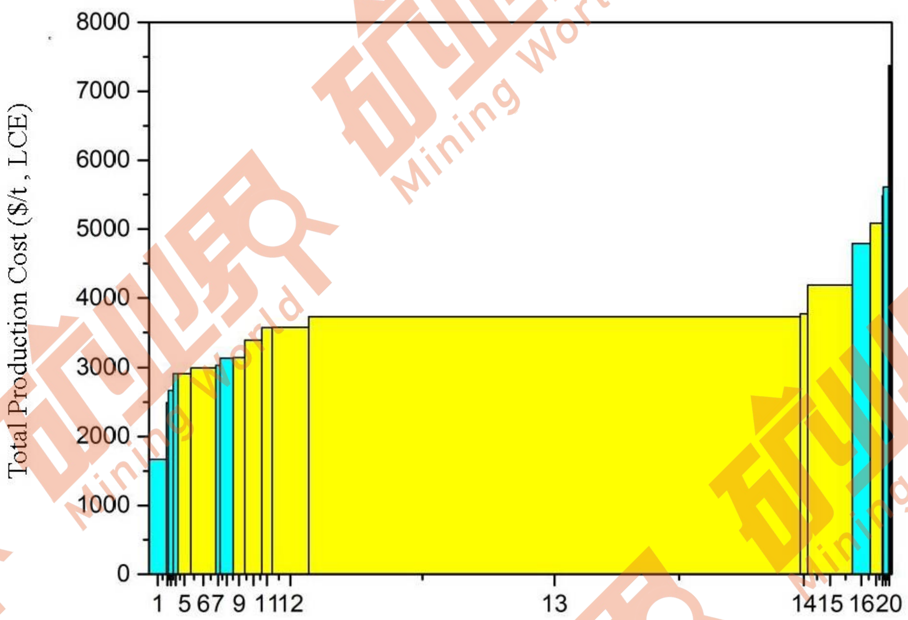
No.	Country	Reserves（1,000 metric tons）	Percentage in the world
1	Chile	52, 670	41. 06%
2	Australia	18, 390[1]	14. 34%
3	Argentina	16, 930[2]	13. 20%
4	China	8, 100	6. 31%
5	USA	5, 700	4. 44%
6	Canada	3, 690[2]	2. 88%
7	Congo(DRC)	3, 630	2. 83%
8	Zimbabwe	2, 430	1. 89%
9	Mexico	1, 730	1. 35%
10	Spain	790[2]	0. 62%
11	Others	14, 220	11. 09%
	Total	128, 280	100. 00%

Note: 1-Australia's official reserves for 2020 are 20 million tons; 2-These data include reserves converted from advanced resources.

US$1600-7400/ton, with an approximate average value of US$3100/ton. In general, mines with larger reserves have lower total production costs. The total production cost of salt-lake type lithium mine is relatively stable (at US$2900-4200/ton) with an average of US$3550/ton, except for one mining project having high cost of US$5088/ton. The relationship between the scale of salt-lake lithium reserves and the total production cost is not particularly clear. The scale of salt-lake lithium reserves is relatively larger compared with the scale of hard rock lithium reserves. The total production cost of the salt-lake lithium mines is between the highest and the lowest value of the total production cost of hard rock lithium; however, if the cost of other associated economic minerals, such as potash, are apportioned, the cost of salt-lake lithium may be significantly reduced. The total production cost of the above-mentioned lithium mine is the total production cost of the project, which include the production cost of other associated economic minerals in the project.

Table 1-2 Major countries with lithium (Li_2CO_3) resources in the world (2020)

No.	Country	Resources（1,000 metric tons）	Percentage in the world
1	Bolivia	111, 760	31. 98%
2	Argentina	79, 340	22. 71%
3	USA	54, 920	15. 72%
4	Australia	20, 620	5. 90%
5	China	19, 140	5. 48%
6	Congo (DRC)	16, 280	4. 66%
7	Canada	14, 620	4. 18%
8	Czech	6, 560	1. 88%
9	Serbia	6, 170	1. 77%
10	Chile	5, 800	1. 66%
11	Others	14, 220	4. 07%
	Total	349, 430	100. 00%

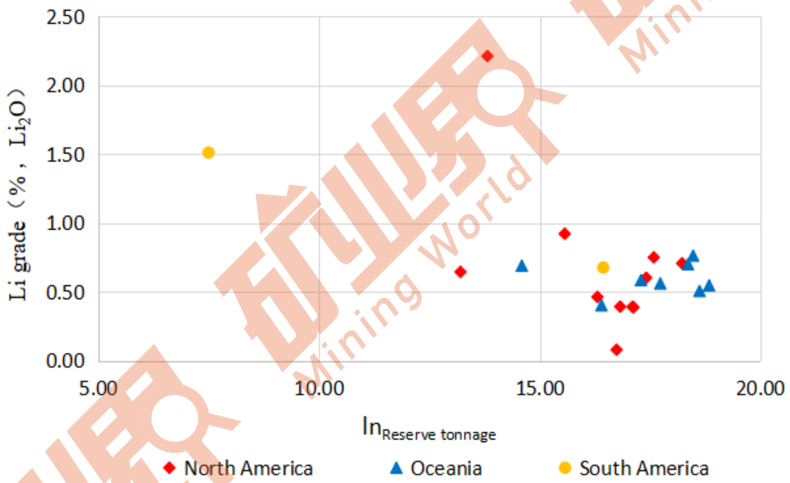


Yellow: brine lithium; Blue: hard rock lithium.

Note: The width of x axis represents the ore tonnage, and the number means the project No..

Fig. 1-2 Reserve tonnage vs. cost model of lithium mines in the world

The average grade of the hard rock lithium mining projects in the world is between 0.4% and 1.0% (lithium metal, as shown below) based on the analysis of tonnage-grade model of 34 lithium mining projects. The scale of reserves is from 17.98 to 150 million tons (Fig. 1-3). There are more lithium deposits distributed in North America and Oceania on a regional perspective. The grades of hard rock lithium mining projects in North America are mostly distributed between 0.4% and 1.0%, with reserve scale ranging between 35,000 tons and 8.47 million tons. The grades of hard rock lithium mining projects in Oceania range from 0.4% to 0.8%, with the ore reserves ranging between 2.18 million tons and 150 million tons. There are few hard rock lithium projects in South America, and the distribution of reserves and grades is uneven, with large-scale projects having relatively lower grades, and vice versa.



Note: The ln $_{Reserve\ Tonnage}$ means the log value of the ore reserves tonnage based on *e*.

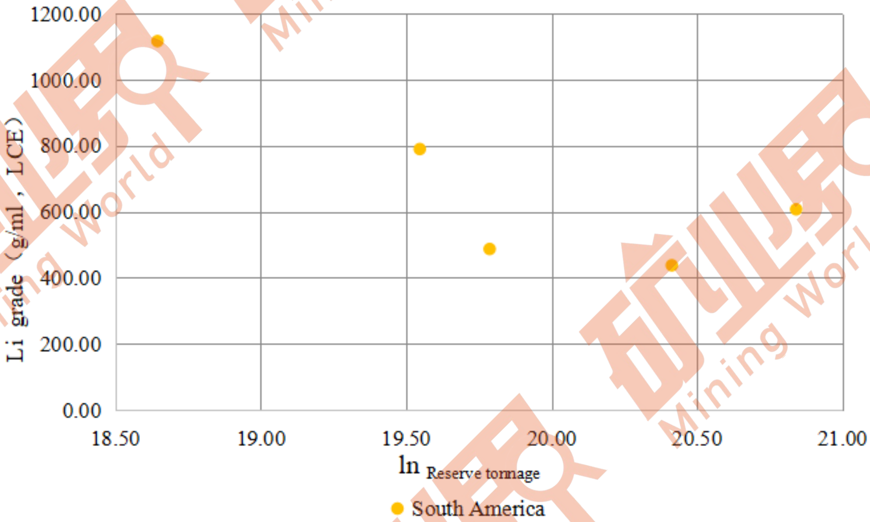
Fig. 1-3 Reserve tonnage vs. grade model of hard rock type lithium deposits in the world

The grades of salt-lake lithium projects range from 400 mg/L to 1200 mg/L (lithium metal, as shown below) (Fig. 1-4). Their ore reserves (brine) range from 120 million to 1.1 billion cubic meters. The grade of lithium ore for larger projects is relatively low in the overall trend, and vice versa.

4. Lithium resource potential

The salt-lake brine type lithium deposits are mainly distributed in the

Lithium Triangle of South America, the Qinghai-Tibet Plateau of China and the western United States. Due to the harsh environment associated with high mountains and deep basins in these regions, a large number of salt-lake brine type lithium deposits have not been systematically explored, and the potential for lithium resources is great.



Note: The ln $_{\text{Reserve Tonnage}}$ means the log value of the ore reserves tonnage based on *e*.

Fig. 1-4 Reserve tonnage vs. grade model of salt-lake type lithium deposits in the world

Pegmatite type lithium deposits are widely distributed in orogenic belts of various geological periods in the world, so there is a huge potential for prospecting. For example, the central region of Nuristan-Pamirs in the central and western Afghanistan, is the world's largest potential area for pegmatite type lithium resource. Due to its huge resource potential, it has been nick-named as the "Arabian lithium" according to the reports from the United States. In addition, the stable cratons in Africa (such as the Congo Craton) and the Guyana Shield in South America are also very important potential areas for pegmatite type lithium deposits.

The resource potential of clay type lithium deposits in the western United States is also great. There are thick lithium-bearing clay layers in the Clayton Valley, Big Sandy, Burro Creek, and Thacker Pass, which have a total lithium resource potential of more than 10 million tons. The borders between western Mexico and the United States are also potential areas for clay type lithium deposits with promising prospecting.

Cobalt (Co)

1. Types and distribution of cobalt resources

There are three main types of cobalt deposits in the world: (1) Sedimentary Cu-Co deposit; (2) Laterite Ni-Co deposit; and (3) Magmatic Ni-Cu(-Co-PGE) deposit. Other types of cobalt deposits include (4) Black shale hosted Ni-Cu-Zn-Co deposit; (5) Skarn Fe-Cu-Co deposit; (6) Iron oxide copper gold type (IOCG type) Cu-Au (-Ag-U-REE-Co-Ni) deposit; (7) Metamorphic sedimentary hosted Co-Cu-Au deposit; (8) Mississippi type Pb-Zn (-Co-Ni) deposit; (9) Hydrothermal metasomatic vein type Co-rich polymetallic deposit; (10) Volcanic massive sulfide type Cu-(Zn-Co-Ag-Au) deposit; and (11) Co-rich Fe-Mn nodules and crusts on the seafloor.

The global cobalt resources are relatively scarce. Most of them occur as associated element in the deposit. In terms of quantifying the total resource, cobalt resources are mainly distributed in Congo (DRC), Indonesia, Australia, Canada, Philippines, Zambia, and New Caledonia. The distribution of cobalt resources in Congo (DRC) presents a highly concentrated feature, as the country is the most important cobalt resource distribution area in the world, and the Central African Copper-Cobalt Belt to its south accounts for nearly half of the world's cobalt resources.

The mining of sedimentary cobalt deposits is mainly concentrated in the Congo (DRC), followed by Zambia; whereas the mining of laterite cobalt deposits is mainly concentrated in countries near the Equator, where cobalt is developed as an associated element of nickel, typically in Australia and Indonesia. The development of magmatic cobalt deposits is widely distributed around the world, classically in Australia, Canada, and Russia, where cobalt is recovered as an associated element.

2. Reserves and resources

(1) Reserves

By the end of 2020, 1202 cobalt projects were recorded in the world, of which 59 have reserves, and are distributed in 20 countries (Fig. 2-1). The estimated global cobalt reserves are 6.68 million tons, which are mainly distributed in Congo (DRC) (44.46%), followed by Indonesia (16.02%), and Australia (9.73%) (Table 2-1). China's cobalt reserves are 130,000 tons, accounting for 1.95% of the world's total. The sedimentary cobalt deposits are the most important type of cobalt deposits, with reserves accounting for about 50.53%, followed by laterite cobalt deposits accounting for 40.02% and magmatic cobalt deposits accounting for 7.01%.

Table 2-1 Major countries with cobalt reserves in the world (2020)

No.	Country	Reserves（1,000 metric tons）	Percentage in the world
1	Congo(DRC)	2,970[1]	44.46%
2	Indonisia	1,070[2]	16.02%
3	Australia	650[3]	9.73%
4	Cuba	250	3.74%
5	Canada	190	2.84%
6	Cameroon	180	2.69%
7	China	130	1.95%
8	New Caledonia	120	1.80%
9	The Philippines	100	1.50%
10	Madagascar	100	1.50%
11	Others	920	13.77%
	Total	6,680	100.00%

Note: 1- It contains 530,000 tons of cobalt reserve converted from advanced resources. 2-From the data issued by Indonesian government in 2019 (Not all the data on the associated cobalt resources of the laterite nickel projects in Indonesia were collected in this report, so the official data of Indonesia are cited here); 3-Australia's official cobalt reserves in 2020 are 560,000 tons.

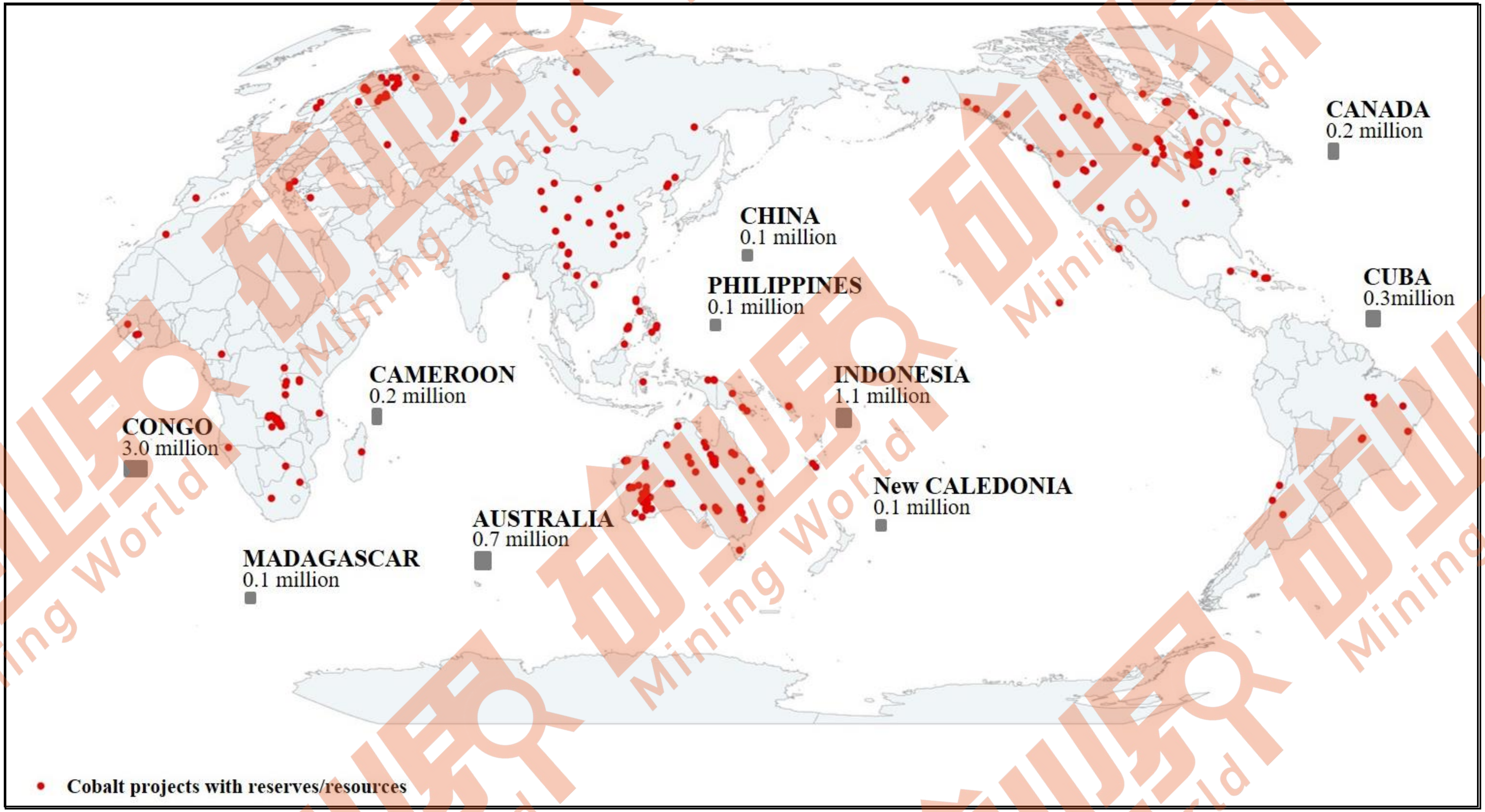


Fig. 2-1 Advanced projects and major countries with cobalt reserves in the world (2020, reserves: metric tons of cobalt metal)

(2) Resources

By the end of 2020, 1202 cobalt projects were recorded in the world, of which 268 have resources, and are distributed in 38 countries. The global cobalt resources are estimated to be 23.44 million tons, with the Congo (DRC) resources being the largest (35.24%), followed by Indonesia (17.70%), Australia (7.30%), Tonga (6.48%) and Canada (4.78%) (Table 2-2). China's cobalt resources are 440,000 tons, accounting for 1.88% of the world's cobalt resources.

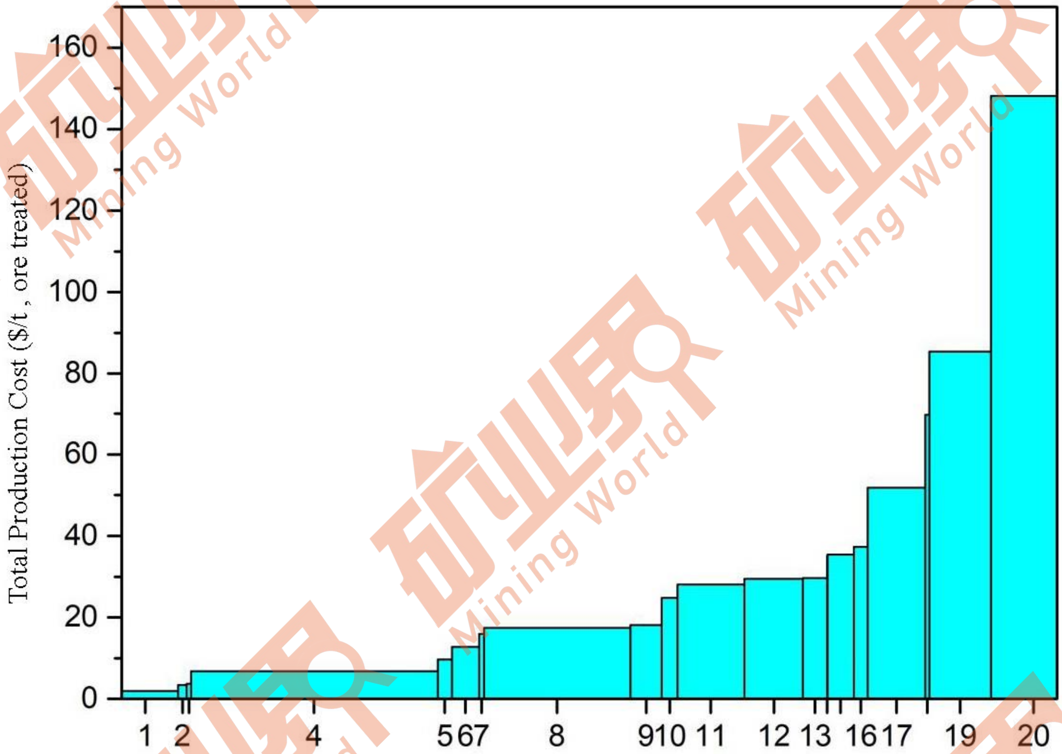
Table 2-2 Major countries with cobalt resources in the world (2020)

No.	Country	Resources（1,000 metric tons）	Percentage in the world
1	Congo (DRC)	8,260	35.24%
2	Indonisia	4,150[1]	17.70%
3	Australia	1,710	7.30%
4	Tonga	1,520	6.48%
5	Canada	1,120	4.78%
6	The Philippines	970	4.14%
7	Cuba	850	3.63%
8	Zambia	680	2.90%
9	New Caledonia	490	2.09%
10	USA	480	2.05%
11	China	440	1.88%
12	Brazil	350	1.49%
13	Papua New	330	1.41%
14	Côte d'Ivoire	290	1.24%
15	Tanzania	230	0.98%
16	Malaysia	190	0.81%
17	Russia	170	0.73%
18	Mexico	160	0.68%
19	Others	1050	4.48%
	Total	23,440	100.00%

Note: 1-From the data issued by Indonesian government in 2019(Not all the data on the associated cobalt resources of the laterite nickel projects in Indonesia were collected in this report, so the official data of Indonesia are cited here).

3. Overview of reserve economy

The apportioned cost of cobalt ranges from US$2.52 to 148.18/ton based on analysis of tonnage-cost (cost of cobalt mine per ton of ore, as shown below) of 20 cobalt projects with associated reserves in the world (Fig. 2-2). In general, there is a reasonable correlation between the scale of reserves and the costs. The costs of mines with larger reserves are relatively low.

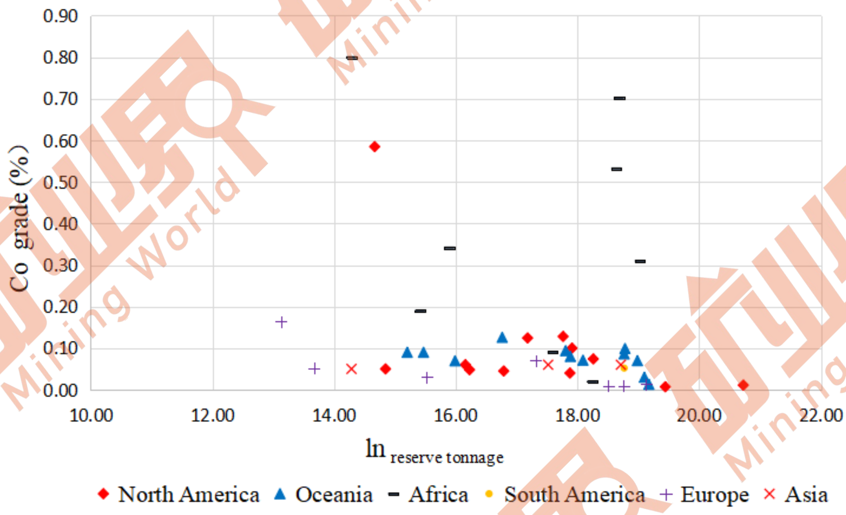


Note: The width of x axis represents the ore tonnage, and the number means the project No..

Fig. 2-2 Reserve tonnage vs. cost of cobalt mines in the world

From a regional perspective, the apportioned production costs of cobalt mines in various continents are also significantly different. The cost in Europe, Asia and North America is the lowest, roughly between US$1.94-37.30/ton, while the cost in Oceania is generally between US$30-50/ton. The total production cost of cobalt mines in Africa is clearly differentiated on three levels. The first level has relatively small cobalt reserves and the apportioned production cost is less than US$30/ton, whereas the second level is valued at US$70-100/ton, and the third level has relatively large cobalt reserves with a cost of about US$150/ton. Considering the fact that just a few projects have the overall reserves and cost data, the results of this analysis serve as a reference only. Although the cost of European cobalt mines in the model is relatively low, caution should be taken when using it due to the small number of projects.

The average grade of most cobalt deposits in North America, Oceania, Europe, and Asia is between 0.01% and 0.15%, and the ore reserves varies greatly from 0.5 million to 300 million tons, based on the analysis of the tonnage-grade model from 43 cobalt projects (Fig. 2-3). The average grade of cobalt projects in Africa is relatively high, with the average grade between 0.2% and 0.8%, and the ore reserves ranges between 5 million and 180 million tons, indicating better cobalt resources in Africa.



Note: The ln Reserve Tonnage means the log value of the ore reserves tonnage based on *e*.

Fig. 2-3 Reserve tonnage vs. grade model of cobalt deposits in the world

4. Cobalt resource potential

The western section of the Copper-Cobalt Belt in Central Africa is currently the most concentrated area for cobalt resources in the world. The area has seen enormous investment and set-up of cobalt projects in recent years. It is the most potential area for cobalt resources. Countries near the equator, such as Western Australia and Indonesia, also have a large number of laterite nickel-cobalt projects under construction in recent years, which are also highly potential areas for cobalt resource. In addition, the Fe-Mn-Co nodules and crusts on the seafloor are important potential cobalt resources for future development.

Nickel (Ni)

1. Types and distribution of nickel resources

There are mainly three types of nickel deposits in the world, i.e. sulfide, laterite, and seafloor polymetallic nodules/ crusts. Currently, sulfide and laterite nickel deposits are the main target for mining.

The global nickel resources are rich and widely distributed in Indonesia, Australia, Russia, Cuba, Brazil, Philippines, New Caledonia, Canada, and China. The laterite nickel deposits predominantly occur in Indonesia, Australia, Philippines, Cuba, Brazil, New Caledonia, and Papua New Guinea. The sulfide type nickel deposits are mainly distributed in South Africa, Canada, Russia, Australia, and China. At present, the global nickel deposits are mainly mined in the above-mentioned countries.

2. Reserves and resources

(1) Reserves

By the end of 2020, 1153 nickel projects were recorded in the world, of which 176 have reserves, and are distributed in 26 countries (Fig. 3-1). The estimated global nickel reserves of 90.63 million tons (Table 3-1) are mainly distributed in Indonesia, Australia, Russia, Cuba, Brazil, Canada, and the Philippines. The laterite nickel reserves are 57.4 million tons, accounting for 63% of the world's total reserves, while the sulfide type nickel reserves are 33.18 million tons, accounting for 37% of the world's total reserves. China's nickel reserves are 3.98 million tons, accounting for 4.39% of the world's nickel reserves.

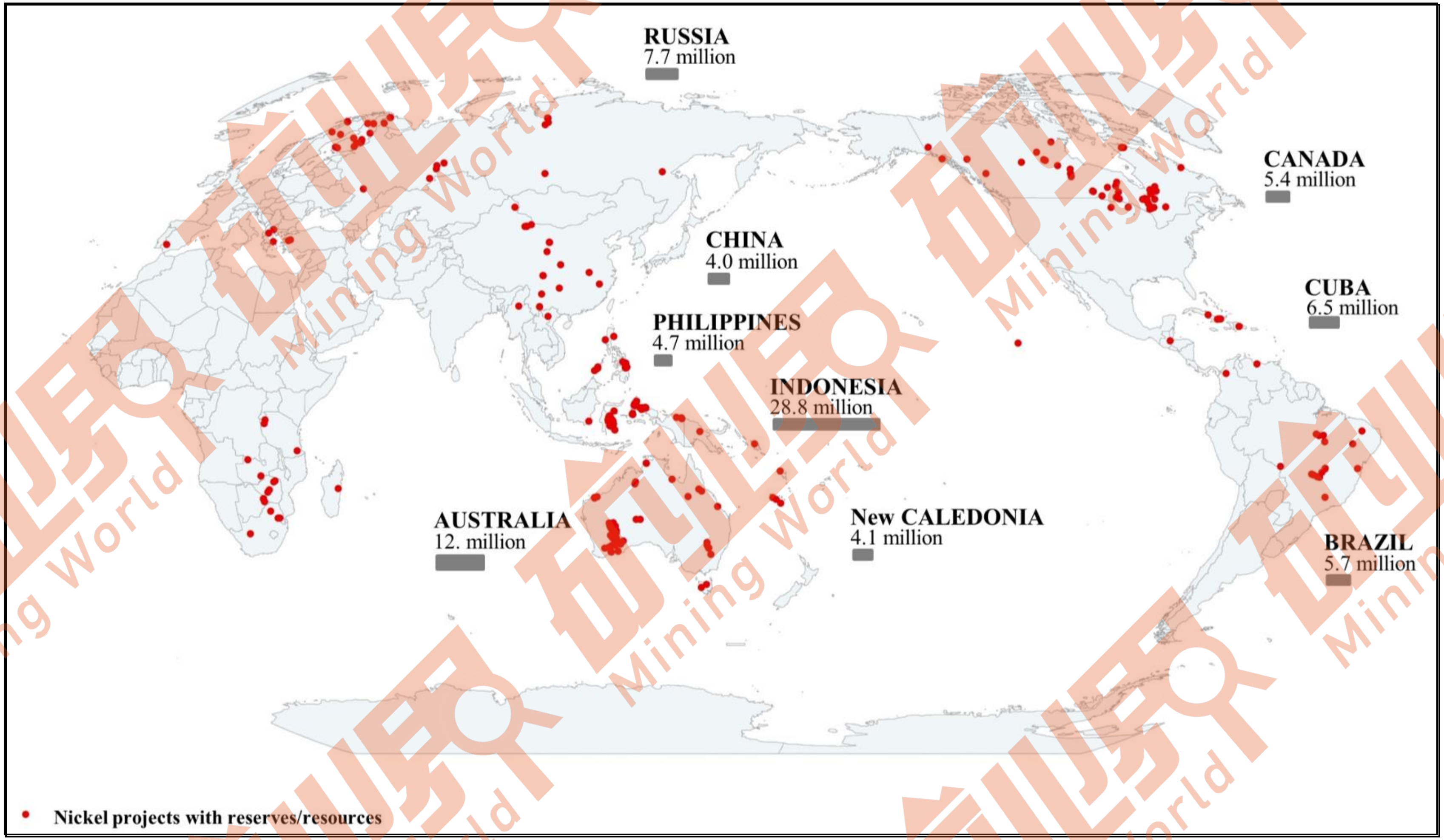


Fig. 3-1 Advanced projects and major countries with nickel reserves in the world (2020, reserves: metric tons of nickel metal)

Table 3-1 Major countries with nickel reserves in the world (2020)

No.	Country	Reserves（1,000 metric tons）	Percentage in the world
1	Indonisia	28,750[1]	31.72%
2	Australia	12,650[2]	13.96%
3	Russia	7,700[3]	8.50%
4	Cuba	6,470	7.14%
5	Brazil	5,670	6.26%
6	Canada	5,420	5.98%
7	The Philippines	4,720	5.21%
8	New Caledonia	4,090	4.51%
9	China	3,980	4.39%
10	South Africa	1,540	1.70%
11	Guatemala	980	1.08%
12	Dominica	930	1.03%
13	Madagascar	790	0.87%
14	Others	6,940	7.66%
	Total	90,630	100.00%

Note: 1-The nickel reserves issued by Indonesian government in 2019 are 71.99 million tons; 2-The nickel reserves reported by Australian government in 2020 are 8.3 million tons; 3-Russia's official nickel reserves in 2020 are 8 million tons.

(2) Resources

By the end of 2020, 391 out of 1153 nickel projects in the world have resources, and are distributed in 37 countries. The global nickel resources are estimated to be 261 million tons, which are mainly concentrated in Indonesia, Australia, Russia, Canada, Brazil, New Caledonia, and the Philippines (Table 3-2). China's nickel resources are 4.1 million tons, accounting for 1.57% of the world's nickel resources.

3. Overview of reserve economy

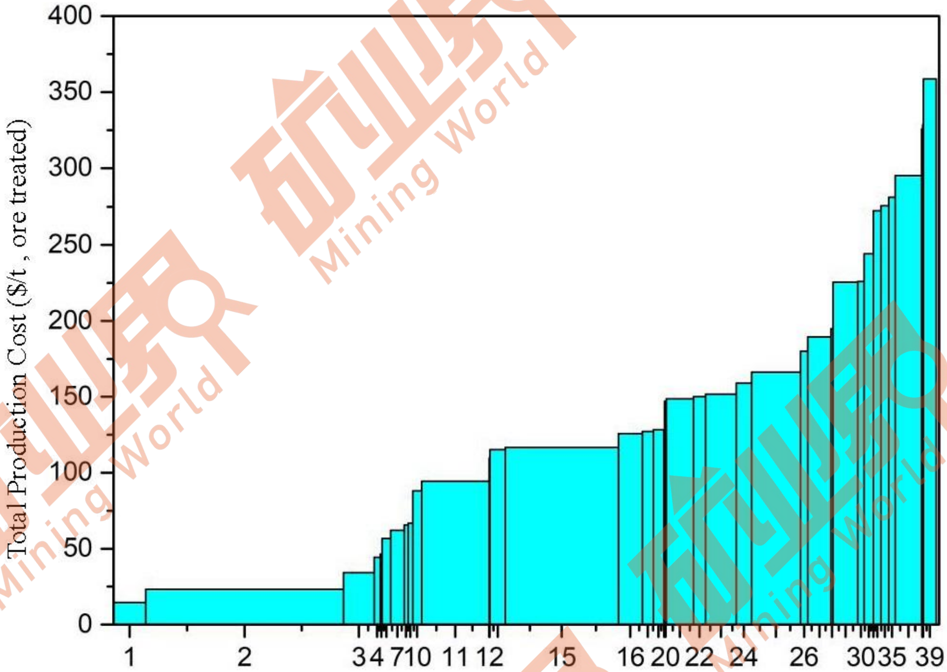
Based on the tonnage-cost (cost of nickel mine per ton of ore, as shown below) analysis of 39 nickel projects with reserves, the costs of nickel projects range from US$15 to 360/ton (Fig. 3-2), with an

Table 3-2 Major countries with nickel resources in the world (2020)

No.	Country	Resources（1,000 metric tons）	Percentage in the world
1	Indonisia	60,710[1]	23.28%
2	Australia	47,020	18.03%
3	Russia	25,670	9.84%
4	Canada	23,090	8.85%
5	Brazil	16,550	6.35%
6	New Caledonia	14,470	5.55%
7	The Philippines	14,320	5.49%
8	Cuba	13,880	5.32%
9	Tonga	9,790	3.75%
10	South Africa	4,670	1.79%
11	China	4,100	1.57%
12	Tanzania	3,660	1.40%
13	Solomon Islands	3,290	1.26%
14	Papua New Guinea	2,600	1.00%
15	Burundi	2,420	0.93%
16	Columbia	2,190	0.84%
17	Greece	2,120	0.81%
18	Guatemala	1,470	0.56%
19	Sweden	1,260	0.48%
20	Albania	960	0.37%
21	Madagascar	930	0.36%
22	Botswana	700	0.27%
23	Others	4,950	1.90%
	Total	260,820	100.00%

Note: 1- The nickel resources issued by Indonesian government in 2019 are 166.93 million tons.

approximate average of US$130/ton. Overall, there is a strong correlation between the scale of reserves and the total production cost. The total production cost of projects with large reserves is lower than that with small reserves. The total production cost of the above-mentioned nickel projects also includes the production cost of other associated elements in the projects.



Note: The width of x axis represents the ore tonnage, and the number means the project No..

Fig. 3-2 Reserve tonnage vs. cost model of nickel mines in the world

From a regional perspective, there are significant differences in the total production costs of nickel projects in different continents. The total production cost of nickel mines is relatively low in Africa, Asia and Europe, with the cost of most mines falling below US$150/ton, while the total production cost of most nickel mines in Oceania is relatively high, ranging from US$150-300/ton. The total production cost of nickel mines in South America is medium, mainly between US$150-225/ton. In contrast, the total production cost of nickel mines in North America is very different, as the mines with large nickel reserves have the production costs between US$50-150/ton, and the mines with small reserves have the production costs between US$225-350/ton.

From the perspective of deposit types, the total production cost of sulfide type nickel deposits related to stratified mafic-ultramafic intrusions is relatively low, mostly below US$65/ton, whereas the total production cost of laterite nickel deposits spans a large range, mostly from US$50 to 250/ton, with a few deposits nearly US$300/ton. The total production cost of other sulfide type nickel deposits related to magmatic rocks also has a large span, with some mines between US$100-150/ton, and others between US$250-350/ton.

Note: The ln $_{\text{Reserve Tonnage}}$ means the log value of the ore reserves tonnage based on *e*.

Fig. 3-3 Reserve tonnage vs. grade model of nickel deposits in the world

According to the analysis of the model of tonnage-grade from 127 nickel projects, the range of grade is 0.2%-2.6%, mostly between 0.5%-2.0%, with an average of about 1.2%. The ore reserves of nickel projects are between 3 million and 680 million tons (Fig. 3-3). Generally speaking, there is no good correlation between tonnage and grade.

From a regional perspective, Asia has the largest amount of nickel deposits. The average grade and reserve scale of Asian nickel projects are relatively scattered, with the average grade between 0.5% and 3.0%, and the reserves ranges between 0.45 million to 300 million tons. The projects with an average grade of more than 2.0% are mainly concentrated in Asia, with small number of projects and varying scales of reserves. The average grade of nickel project in Oceania and Africa is between 0.5%-1.5%, generally with large scale of reserves, while the average grade of nickel projects with different scale of reserves in Europe is between 0.25%-1.5%, which is slightly lower.

4. Potential of nickel ore resources

The southern Philippines and northeastern Indonesia (especially in Sulawesi) are great potential zones for prospecting laterite nickel deposits. South America and northeastern Africa are potential areas for exploring copper-nickel sulfide deposits related to the Large Igneous Province. In the orogenic belt, the post-collisional setting also has the potential to form copper-nickel sulfide deposits (such as in the Central Asian Orogenic Belt). The potential of nickel resources in oceanic polymetallic noddles/crusts is huge, which is an important direction for nickel resource exploration in the future.

Tin (Sn)

1. Types and distribution of tin resources

Global tin deposits can be divided into six main types, i.e. porphyry type, greisen type, skarn type, quartz vein type, cassiterite-sulfide type, and alluvial type. The alluvial type tin deposits are formed after various types of primary tin deposits are being weathered and transformed. Most of them occur in Southeast Asia in the Cenozoic.

The tin deposits are widely distributed in the world. However, they often occur as “cluster” or "belt". According to the characteristics of tin deposits, three main tin belts can be recognized, including the giant tin belt in Rim Pacific Ocean, the intracontinental tin belt in Eurasia, and the tin belt in central-southern Africa. The tin reserves in the giant tin belt of the Rim Pacific Ocean exceed 80% of the world's total reserves, and the mineralization principally took place during Mesozoic and Cenozoic.

The development of tin mine is mainly concentrated in a few countries, such as China and countries in Southeast Asian (including Indonesia and Malaysia), Bolivia in South America, and some countries in Central and Southern Africa.

2. Reserves and resources

(1) Reserves

By the end of 2020, 132 tin projects in the world were recorded, of which 27 have reserves, and are distributed in 15 countries (Fig. 4-1). The global tin reserves are estimated to be 3.27 million tons, and are concentrated in China (23.24%), Russia (13.15%), Brazil (12.84%), Australia (11.93%), Indonesia (10.40%), and Malaysia (7.65%) (see

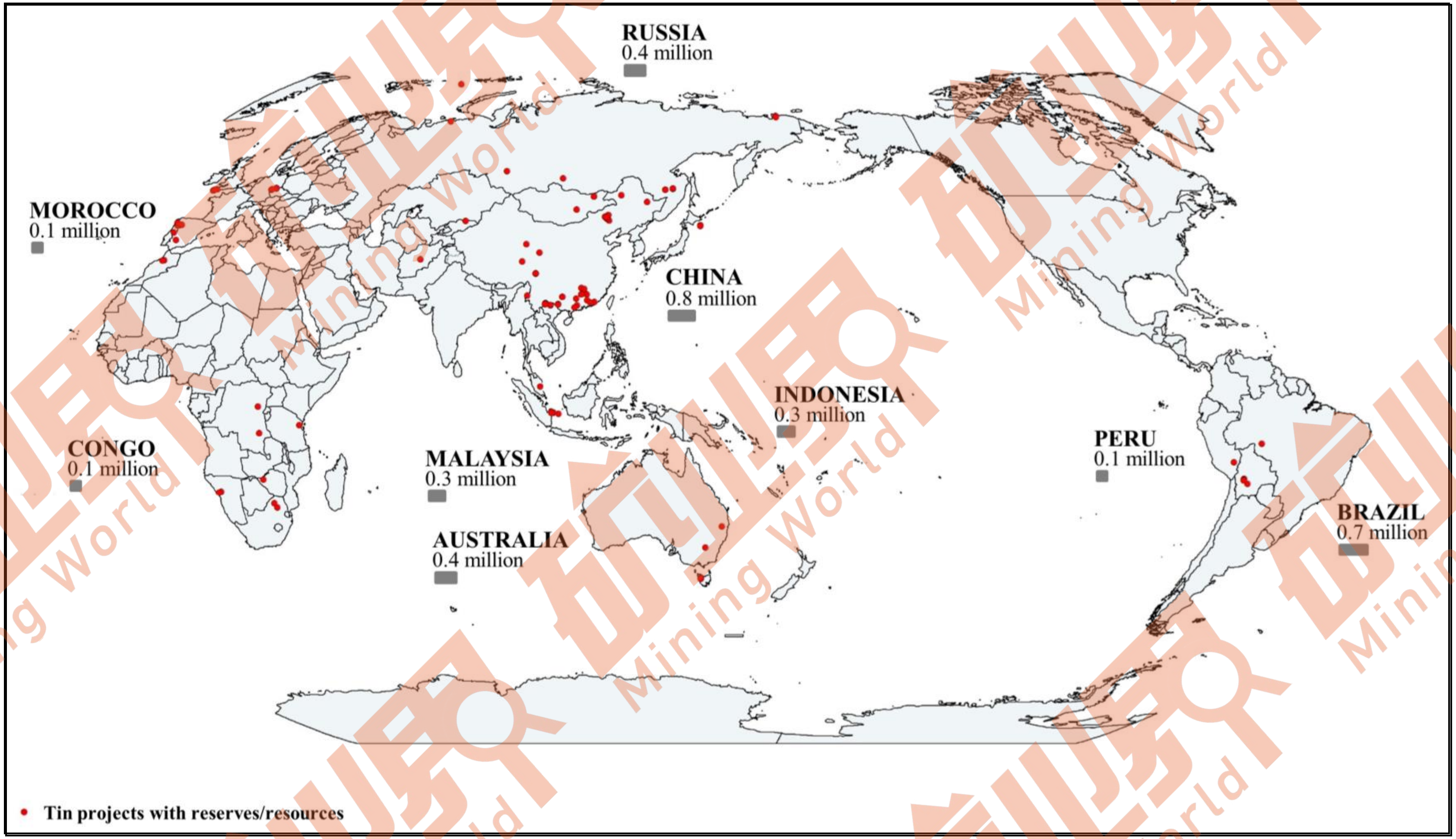


Fig. 4-1 Advanced projects and major countries with tin reserves in the world (2020, reserves: metric tons of tin metal)

Table 4-1).

Table 4-1 Major countries with tin reserves in the world (2020)

No.	Country	Reserves (1,000 metric tons)	Percentage in the world
1	China	760	23.24%
2	Russia	430[1]	13.15%
3	Brazil	420[2]	12.84%
4	Australia	390[3,4]	11.93%
5	Indonisia	340	10.40%
6	Malaysia	250[2]	7.65%
7	Congo (DRC)	140	4.28%
8	Peru	140	4.28%
9	Morocco	60	1.83%
10	Kyrgyzstan	20	0.61%
11	Others	320	9.79%
	Total	3,270	100.00%

Note: 1-The tin ore reserves reported internally and externally by Russian government in 2020 are 1.59 million tons and 200,000 tons, respectively; 2- From Mineral Commodity Summaries 2021 by USGS; 3-It contains 240,000 tons of reserves converted from advanced resources; 4-Australia's official reserves for 2020 are 260,000 tons.

(2) Resources

By the end of 2020, 52 out of 132 tin projects in the world have resources, and are from 18 countries. The global tin resources are estimated to be 8.07 million tons, mainly distributed in China (41.88%), Bolivia (10.16%), and Indonesia (9.29%). Tin resources in other countries are relatively small (Table 4-2).

3. Overview of reserve economy

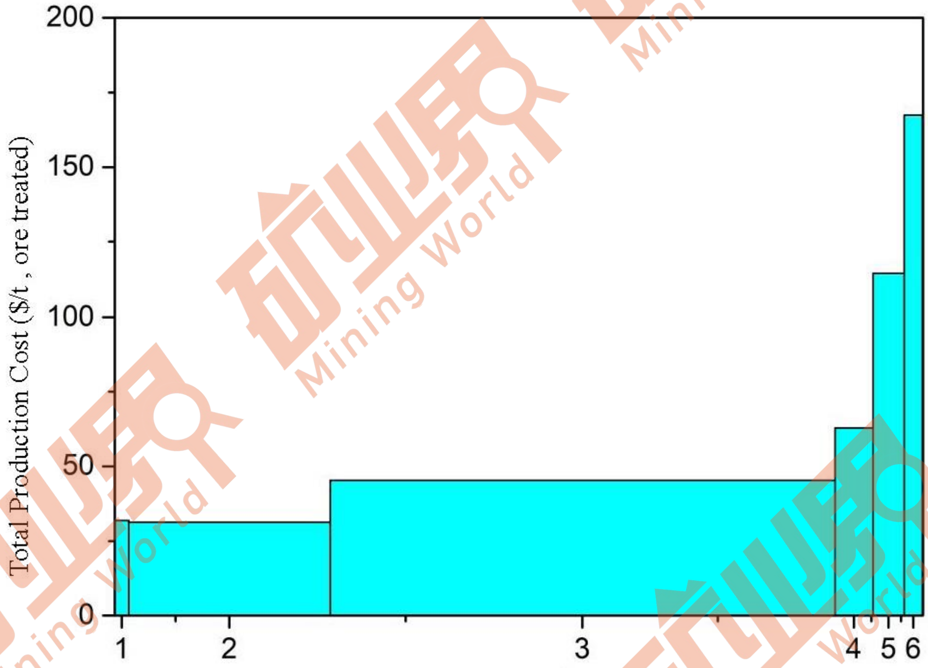
According to the analysis of tonnage-cost model (cost of tin mine per ton ore, as shown below) for 6 tin projects in the world, the cost ranges from US$60 to 170/ton, with an average approximation of US$100 /ton (Fig. 4-2). The large-scale tin mines have a total production cost of less than US$80/ton. The total production cost of the tin mine also include the production costs of other associated elements in the mine.

Table 4-2 Major countries with tin resources in the world (2020)

No.	Country	Resources（1,000 metric tons）	Percentage in the world
1	China	3,380	41.88%
2	Bolivia	820	10.16%
3	Indonisia	750	9.29%
4	Russia	540[1]	6.69%
5	Kazakhstan	490	6.07%
6	Australia	370	4.58%
7	Czech	280	3.47%
8	Peru	230	2.85%
9	Congo(DRC)	220	2.73%
10	Germany	220	2.73%
11	Others	770	9.54%
	Total	8,070	100.00%

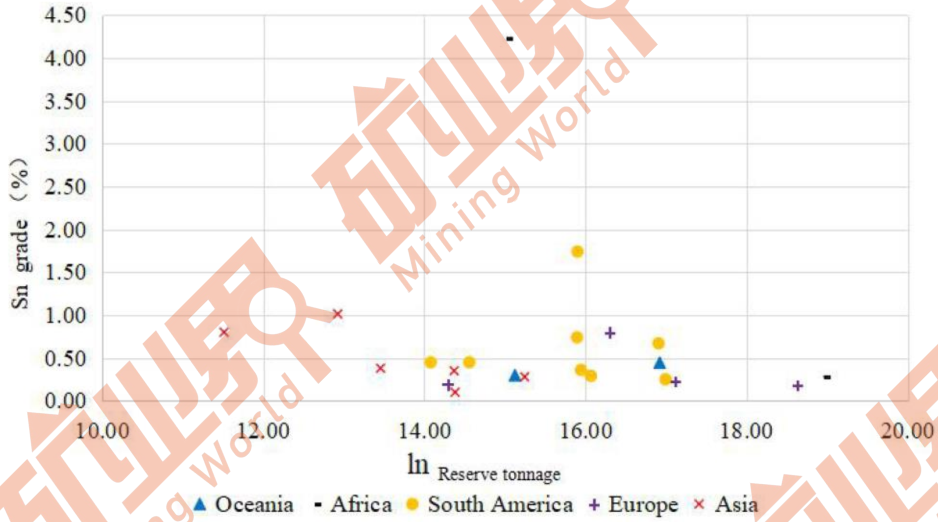
1- The tin resources (C_2) announced internally by Russian government in 2020 are 530,000 tons.

By analyzing the tonnage-grade model of 29 tin projects, the ore grades range from 0.1% to 4.2%, mostly less than 1.0%, with an average grade of about 0.4% (Fig. 4-3). Except for a few projects, the grades of tin projects in South America and Asia are below 1.0%, with the reserves between 100,000 and 170 million tons. Spatially, more tin projects are distributed in South America and Asia, followed by Europe. In terms of ore tonnage, the ore reserves of most tin projects in Asia are between 100,000 and 4.18 million tons, which are smaller than those in South America with the ore reserves between 5.85 million and 150 million tons. Although the number of tin projects in Europe is small and the ore grade is not high, the ore reserves are relatively large, ranging from 1.3 million to 24 million tons. The Bisie tin mine in Africa has a high grade of 4.23% Sn, with an ore reserve of 3.33 million tons.



Note: The width of x axis represents the ore tonnage, and the number means the project No..

Fig. 4-2 Reserve tonnage vs. cost model of tin mines in the world



Note: The ln $_{\text{Reserve Tonnage}}$ means the log value of the ore reserves tonnage based on *e*.

Fig. 4-3 Reserve tonnage vs. grade model of tin deposits in the world

4. Tin resource potential

The formation of primary tin deposits is closely related to S-type granites or highly-fractionated I-type granites. According to the discovered tin deposits and the distribution of global granite, it is revealed that the prospecting potential of global tin resources is still large, mainly in Southeast Asia, South America, central section of Tethys metallogenic domain, and parts of Europe. In China, in addition to the major tin concentration area in South China where still there is a large prospecting potential; there have been new findings of large-sized tin deposits in the south-central part of the Great Xing'an Range and southern Tibet in recent years. It indicates that these areas have large tin prospecting potential to supplement the reduction of tin reserves due to continuous mining.

Potash (K)

1. Types and distribution of potash resources

There are three types of potash deposits, including sedimentary type, salt-lake type (Quaternary), and underground brine type. The sedimentary potash deposits is further subdivided into three sub-types, i.e. chloride type, sulfate type, and mixed type, according to their main mineral composition.

The global potash resources are extremely abundant. However, the distribution of potash resources is very uneven. The world-class potash basins and super-large potash deposits that have been discovered around the world are mainly in North America, Europe, South America and Asia, among which Russia, Canada, and Belarus are the richest in potash resources. The development of potash projects in the world is also mainly concentrated in these countries.

2. Reserves and resources

(1) Reserves

By the end of 2020, 306 potash projects in the world were recorded, of which 48 have reserves, and originate from 15 countries (Fig. 5-1). The estimated global potash reserves of 12.9 billion tons (KCl equivalent, as shown below) are mainly in Russia (38.16%), Canada (25.38%), Belarus (10.03%), and Turkmenistan (7.61%), and the rest in other countries (Table 5-1). China's potash reserves are 317 million tons, accounting for 2.46% of the world’s potash reserves.

(2) Resources

By the end of 2020, 51 out of 306 potash projects in the world have

Fig. 5-1 Advanced projects and major countries with potash reserves in the world (2020, reserves: metric tons of KCl equivalent)

Table 5-1 Major countries with potash (KCl) reserves in the world (2020)

No.	Country	Resources（1,000 metric tons）	Percentage in the world
1	Russia	4, 914, 590[1]	38. 16%
2	Canada	3, 269, 100[2]	25. 38%
3	Belarus	1, 291, 470	10. 03%
4	Turkmenistan	980, 620[3]	7. 61%
5	China	317, 000	2. 46%
6	Laos	237, 360	1. 84%
7	Brazil	228, 800	1. 78%
8	Germany	209, 400	1. 63%
9	USA	82, 480	0. 64%
10	UK	64, 620	0. 50%
11	Others	1, 283, 950	9. 97%
	Total	12, 879, 390	100. 00%

Note: 1-This reserve contains some potash projects with the sum of categories A+B+C1 calculated by using the Soviet reserves classification system, without subdividing them. However, considering that these mines are mostly in production, these resources/reserves data are treated as reserves, without deducting the mining losses and dilution. In 2020, the potash (KCl) reserves reported internal and external by the Russian government were 4.723 billion tons and 1.334 billion tons, respectively; 2-It contains 1.528 billion tons of KCl equivalent that converted from advanced resources; 3-Cited from from a visiting report in 2005. It is also the the sum of categories A+B+C1 calculated by using Soviet reserves classification system and mined by the underground mining method, without deducting the potash reserves consumed by the actual production of the mine. The category C1 of 278 million tons of KCl measured by underground dissolution method are not included in this reserve data.

resources, and are from 17 countries. The global potash resources are estimated to be 43 billion tons, which are mainly concentrated in Russia (48.79%) and Canada (34.78%), with a small amount distributed in other countries (Table 5-2). China's potash resources are 430 million tons, accounting for 1.02% of the world’s poash resources.

3. Overview of reserve economy

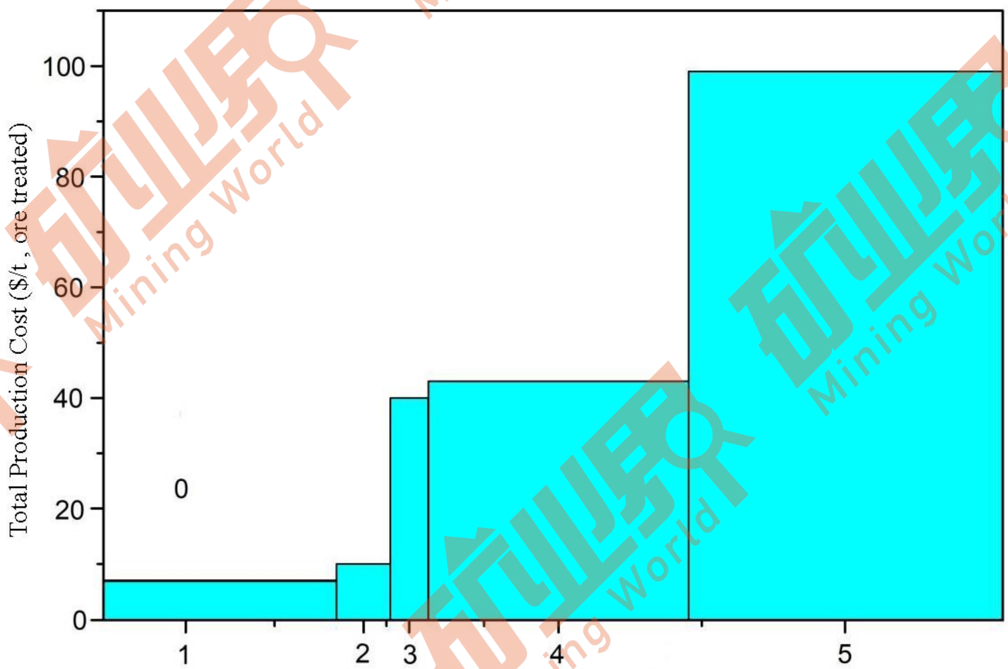
The cost ranges from US$7/ton to US$99/ton (ton of ore) was achieved by analyzing the tonnage-cost model of the 5 potash projects in the world, with the average cost of nearly US$60/ton (Fig. 5-2). There are

Table 5-2 Major countries with potash (KCl) resources in the world (2020)

No.	Country	Resources（1,000 metric tons）	Percentage in the world
1	Russia	20, 966, 910[1]	48. 79%
2	Canada	14, 949, 080	34. 78%
3	Kazakhstan	1, 629, 200	3. 79%
4	Republic of the	1, 349, 980	3. 14%
5	Germany	829, 150	1. 93%
6	USA	673, 560	1. 57%
7	Belarus	718, 890	1. 67%
8	Brazil	472, 240	1. 10%
9	China	436, 600	1. 02%
10	Angola	282, 560	0. 66%
11	Others	668, 380	1. 56%
	Total	42, 976, 550	100. 00%

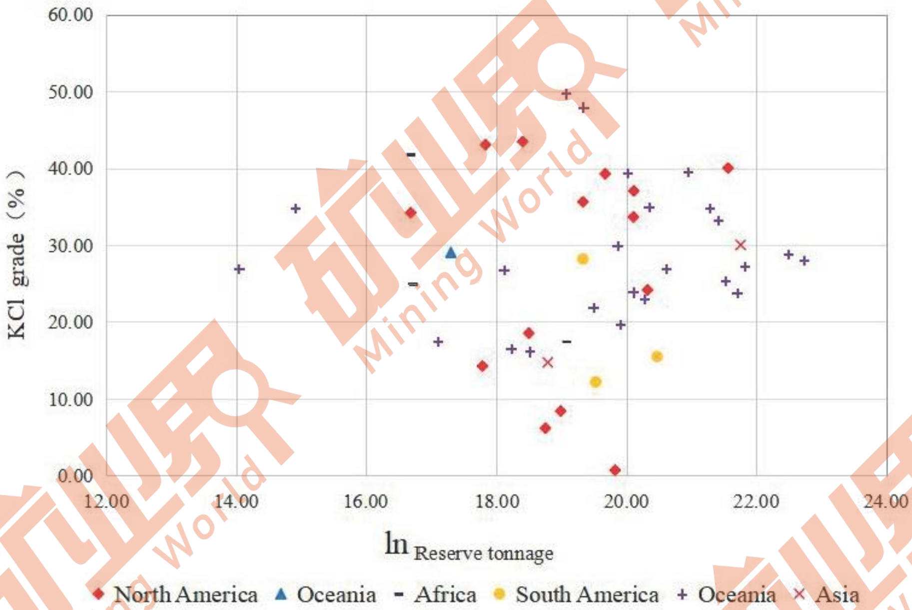
Note 1: In 2020, the potash (KCl) resources announced internally by the Russian government are 20.92 billion tons.

few associated components in potash deposits. So, the total production cost is often the cost of potash production. Generally, the correlation between the scale of reserves and total production costs is not strong.



Note: The width of x axis represents the ore tonnage, and the number means the project No..

Fig. 5-2 Reserve tonnage vs. cost model of potash mines in the world



Note: The ln $_{Reserve\ Tonnage}$ means the log value of the ore reserves tonnage based on *e*.

Fig. 5-3 Reserve tonnage vs. grade model of potash deposits in the world

Based on analyzing the tonnage-grade model of 50 potash projects, the ore grade range of potash is 10%-50% KCl, with an average of about 25% KCl (Fig. 5-3). The potash ore reserves are between 1 million tons and more than 10 billion tons. In general, the differences of average grade and reserve scale between different potash projects are very large. The number of potash projects that have reserves is relatively small in Oceania, Africa, South America, and Asia, with the average grade of potash mostly between 10% and 30%, and the ore reserve between 18 million and 2.8 billion tons.

4. Potash resource potential

The "Belt and Road" regions spanning the metallogenic domains of Laurasia, Tethys, and the Circum-Pacific, are rich in potash resources along the route, and have great potential for potash resources. The main potash-forming basins include Karakum Basin, Pre-Caspian Basin, Khorat-Sakon Nakhon Basin, Vientiane-Gammun Basin, Danajir Rift Basin, Zeichstein Basin, Piripyat Basin, Pre-Ural depression, Qaidam

Basin, and Lop Nur Basin. In addition, the potash deposits have been discovered in the Cotier Basin (also known as the coastal basin) in the west of the Republic of Congo and the Gabon Basin in Gabon, with the former being estimated to have KCl equivalent resources of more than 10 billion tons.

Appendix

1. Explanation of terms

Reserves: An economically recoverable part of the proven mineral resources. It is used in this report as follows:

(1) Based on the CRIRSCO reserve classification, the collected reserve data include proven reserve and probable reserve.

(2) Part of high-level resources in some mining projects will be converted into reserves by adopting certain evaluation methods as needed.

(3) China's mineral resource and reserve classification has not yet completed the conversion from GB/T17766-1999 standard to GB/T 17766-2020 reserve classification. Therefore, this report evaluates the latest resources and reserves data under the original standard according to their availability.

Resources: A mineral resource is identified by certain engineering control. It is used in this report as follows:

(1) Based on the CRIRSCO classification, the resource data collected include measured, indicated and inferred resources, and exclude potential resources such as predicted resources.

(2) The amount of resources in China is in accordance with the amount of resources of (333) and above in the original standard.

(3) **Reserves and resources in this report do not include each other; thus, resources do not include reserves.**

2. Data source

The resources and reserves data in this report were updated up to the end of 2020.

A total of 3,168 mining projects worldwide, including mines in production and out of production, mining projects under exploration, pre-feasibility studies, or feasibility studies, for the above five minerals were collected from multiple sources, such as company reports (including annual/reserve reports, exploration reports, company websites/internal reports), commercial databases, government or official websites, and literature, in an effort to ensure that no large or medium-sized mining projects are missed out. The data collected are mainly from the company reports and data published by the governments.

Of the 3,168 mining projects recorded, 987 have resources/reserves data, which are verified by multiple parties to ensure its authenticity, timeliness, traceability, and updatability. Theoretically, it is impossible to collect the reserve data of all the mining projects in the world. Therefore, the mathematical statistical method is adopted to establish a reserve distribution model and estimate the proportion of uncollected and missing reserves.

3. Technical routes for evaluation and methods for processing special data

(1) Technical routes for evaluation

Multi-channel data collection (to ensure that the data collection is comprehensive and true) →screening and verification (remove abnormalities, inspect and verify data, and ensure data reliability) →reserve/resource data standard transformation (data standard transformation in different reserve classification systems) →part of resources are converted to reserves→model analysis (inferring the proportion of uncollected reserves through the mathematical model of reserves distribution)→statistical summary (national distribution of reserves and cost-quality analysis, etc.).

(2) The principle of converting resources to reserves

For some mining projects that have actually been mined, but only published resources data, an assessment was carried out by converting resources to reserves. During conversion, different categories of resources are converted to the “reserves” together, which are not subdivided into proved and probable reserves. Based on the economic assessment of the actually mined resources, the reserve conversion is carried out if the result is economically recoverable. Here is the conversion formula:

Reserve = (Measured + Indicated) resource * average recovery rate AERR

The average recovery rate AERR here refers to the average recovery rate of a typical mine in the model.

Once the resources are converted to reserves, it cannot be double-counted in the resource category, i.e. the resources that have been converted will be deducted from the final resources.

(3) Methods for processing special data

Due to the lack of reserves data in some of the productive mines , the method of converting resources to reserves introduced above was adopted to convert some or all of the high-leveled resources into reserves, including 12 lithium projects, 5 cobalt projects, 1 potash project and 1 tin project in this report.

With regards to the 7 potash projects, the collected resources and reserves data are the sum of categories A+B+C1 based on the Soviet reserves classification system, without subdividing them. However, considering that these mines are in production, these resources/reserves data were treated as reserves, without deducting the mining losses and dilution.

The Indonesian cobalt resources and reserves data are cited from the publication by the Ministry of Energy and Mineral Resources of Indonesia, and not from the mining projects in Indonesia.

The domestic reserves and resources data for these five minerals were obtained by reassessment using data from the 2020 National Mineral Reserves Report.

Assessment Report for Lithium, Cobalt, Nickel, Tin, and Potash Reserves in the World (2021)

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