# A STUDY TO COPPER MINES & INDUSTRIES WITH AN OUTLOOK TO IRAN MARKET

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## 1. INTRODUCTION

**Copper** is a member of the first row transition series of elements, which consists of Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu and Zn, and belongs to group 11 of the periodic table, along with Ag and Au.

Figure 1. Copper

Source: Wikipedia.com

The element has an atomic number of 29, an atomic mass of 63, two main oxidation states (+1 and +2) and two naturally occurring isotopes (63Cu and 65Cu), with abundances of 69.17% and 30.83% respectively. In spite of a similarity in electronic structure, there are few resemblances between the chemistry of the three elements in group 11, although certain complexes of $Cu^{2}$+ and $Ag^{2}$+ are isomorphous.

Table 1. Physical and Mechanical Properties of Copper

| | |
|---|---|
| Color | Reddish-Brown metal |
| Malleability | Capable of being shaped or bent |
| Ductility | Easily pulled or stretched into a thin wire |
| Luster | Has a shine or glow |
| Conductivity | Excellent transmission of heat or electricity |
| Crystal structure | FCC |
| Atomic number | 29 |
| Atomic weight | 63.546 |
| Density | 8.933 gr/cm$^{3}$ |
| Melting point | 1084.62$^{o}$C |

Copper is a chalcophile element forming several minerals, including chalcopyrite $CuFeS_2$, covellite CuS, and malachite $Cu_2CO_3(OH)_2$, but is more widely dispersed at trace levels in mica (biotite), pyroxene and amphibole, thus showing a greater affinity for mafic than for felsic igneous rocks. Copper can occur in its metallic form in nature (i.e., native copper), and is one of the seven metals known in antiquity. [1]

Figure 2. Chalcocite (Cu2S,Copper sulphide)
Source: galleries.com/chalcocite

Figure 3. Chalcopyrite (CuFeS2, copper iron sulphide)
Source: geevor.com

Figure 4. Malachite ($Cu_2CO_3(OH)_2$)

Source: earthsciences.hku.hk

Copper and copper alloys are widely used in a variety of products that enable and enhance our everyday lives. Coppers and certain brasses, bronzes and copper nickels are used extensively for automotive radiators, heat exchangers, home heating systems, solar collectors, and various other applications requiring rapid conduction of heat across or along a metal section. Because of their outstanding ability to withstand corrosion, coppers, brasses, bronzes and copper nickels are also used for pipes, valves and fittings in systems carrying potable water, process water or other aqueous fluids, and industrial gases. [2]

Copper is easily stretched, molded, and shaped; is resistant to corrosion; and conducts heat and electricity efficiently. As a result, copper was important to early humans and continues to be a material of choice for a variety of domestic, industrial, and high-technology applications today. [3]

## 2. COPPER HISTORY

**Copper** was one of the first metals ever extracted and used by humans, and it has made vital contributions to sustaining and improving society since the dawn of civilization. Copper was first used in coins and ornaments starting about 8000 B.C., and at about 5500 B.C., copper tools helped civilization emerge from the Stone Age. The discovery that copper alloyed with tin produces bronze marked the beginning of the Bronze Age at about 3000 B.C. [4]

Figure 5. Copper Casting
Source: swiss-artfoundry.com

In all the moments of history of ancient world, copper contributed immensely to the development of the civilization and the culture, like we saw it in temple doors and many others architectural elements of the Egyptians; needles of copper in the ruins of the second city of Troy; bells and cauldrons of China; classic statues of the Hellenic world; bull’s head fused in copper in the real cemetery of Ur, Mesopotâmia; copper tubes for water in Egypt; axles, swords and knives; ornaments and varied articles.[5]

Figure 6. Copper Ancient Coins
Source: sbbcnews.com

## 3. APPLICATION OF COPPER

Copper and copper alloys can be used in an extraordinary range of applications.

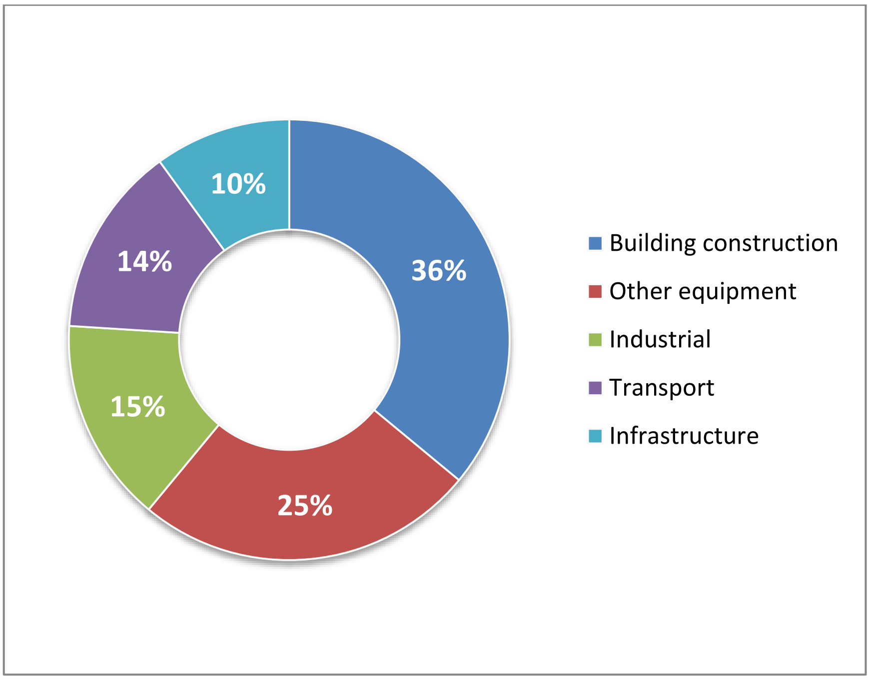


Figure 7.Use of refined copper, by sector, within EU 28

Source: IWCC / ICA, 2015

Some of these applications include:

- Power transmission lines
- Architectural applications
- Cooking utensils
- Spark plugs
- Electrical wiring, cables and bus bars
- High conductivity wires
- Electrodes
- Heat exchangers and refrigeration tubing
- Plumbing
- Water-cooled copper crucibles [6]

Figure 8. Copper Applications

Source: European Copper Institute Copper Alliance

The largest end use for copper is in the building industry. Within the building industry the use of copper-based materials is broad. Construction industry related applications for copper include:

Roofing

- Cladding
- Rainwater systems
- Heating systems
- Water pipes and fittings
- Oil and gas lines
- Electrical wiring [6]

Figure 9. Some of Copper Applications

Source: copper-turned-parts.brass-copper-fittings.com

## 4. COPPER IMPORTANCE AND ADVANTAGES

Used for its superior electrical and thermal conductivities, its ability to be alloyed with other metals in order to enhance performance, plus its durability and strong recycling credentials, copper is an important enabler for innovation in renewable energies, energy efficiency, sustainable buildings, and transport systems. [7]

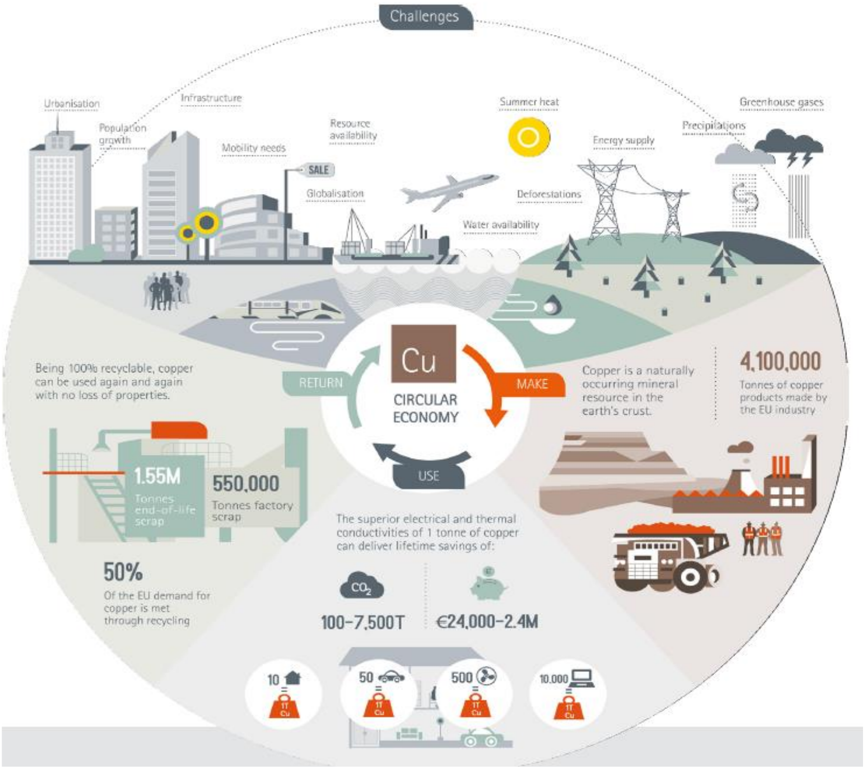


Figure 10. Copper Circular Economy

ICSG Figures, 2014

Besides good conductivity the properties include strength, hardness, ductility, resistance to corrosion, wear and shock, low magnetic permeability, an attractive range of colors together with ease of machining, forming, polishing and plating. Over the years a number of materials have been developed giving combinations of these properties that are optimum for a very wide variety of applications.

It is a ductile metal with excellent electrical conductivity, and finds extensive use as an electrical conductor, heat conductor, as a building material, and as a component of various alloys.

Copper is a reddish-colored metal, with a high electrical and thermal conductivity (silver is the only pure metal to have a higher electrical conductivity at room temperature). Pure copper's melting point is 1,981ºF (1,083ºC).

Like gold and silver, copper is malleable. That is, it can be bent and shaped without cracking, when either hot or cold. It can be rolled into sheets as thin as 1/500 of an inch.

Copper also is ductile, that is, it can be drawn out into thin wire. A copper bar 4 inches thick can be heated, rolled, then drawn into a round wire so thin that it is thinner than a human hair. This wire is 20 million times longer than the original bar!

Industry valued copper for these properties. Copper is second only to silver in its ability to conduct electricity, but silver is too expensive for this sort of use. Bronze and brass, however, do not conduct electricity as well as pure copper.

Besides electricity, copper also is an excellent conductor of heat, making it an important metal in cookware, refrigerators, and radiators.

Copper is resistant to corrosion, that is, it will not rust. If the air around it often is damp, it will change from its usual reddish orange color to reddish-brown. Eventually, it is coated with a green film called a "patina" that stops all further corrosion.

The melting point of copper is 1083.4 degrees Centigrade. Liquid copper boils at 2567 degrees Centigrade.

## Durability

Copper’s corrosion resistance properties mean that they don't tarnish easily - i.e. they stay nice and shiny for a long time. Copper can be recycled when reach the end of its useful life. It can be melted down to make new copper alloys. Or it is possible to refine them using electrolysis to make very high purity copper (99.9% pure).

Numerous reports by institutes specialized in research of quality and durability of copper tubes highlight their stability in environments where they are installed. The lower limit of their stability is proved for the minimum period of 50 years, not only regarding the external environment (when they are installed into earth, wall, mortar, concrete, plaster ...) but also to the effect of fluids transported through them. They are particularly resistant to water (hot and cold) and to numerous industrial liquids, solutions and gasses.

Installation

Copper tubes are joined together using fittings. Professional pipe fitters usually opt for one of the following methods to join copper tubes:

- soft soldering;
- hard soldering;
- mechanical fittings;
- combined fittings.

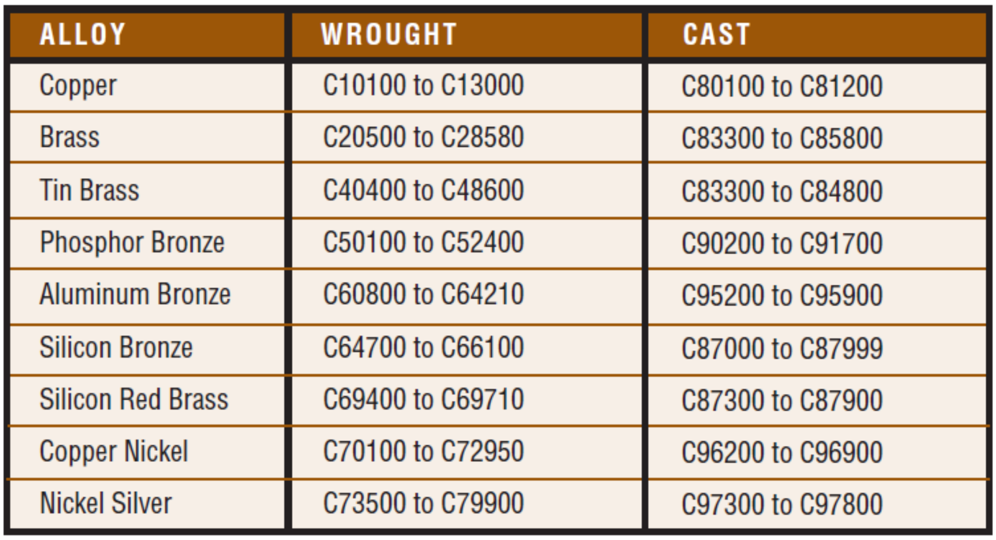
Straight pieces can be joined together without fittings, so as to widen the pipe end with suitable tool, i.e. to make a bell and insert the end of another tube into it and solder them together.

Copper tube joints are compact, solid and resistant to high pressures, dynamic shocks and vibrations. [8]

## 5. COPPER ALLOYS FAMILIES

Copper alloys are identified by the Unified Numbering System (UNS) which categorizes families of alloys based upon their elemental make-up. Wrought products range from UNS C10000 through UNS C79999; cast products are assigned numbers between UNS C80000 and UNS C99999. [9]

Table 2: UNS Copper Alloy Designations



| ALLOY | WROUGHT | CAST |
|---|---|---|
| Copper | C10100 to C13000 | C80100 to C81200 |
| Brass | C20500 to C28580 | C83300 to C85800 |
| Tin Brass | C40400 to C48600 | C83300 to C84800 |
| Phosphor Bronze | C50100 to C52400 | C90200 to C91700 |
| Aluminum Bronze | C60800 to C64210 | C95200 to C95900 |
| Silicon Bronze | C64700 to C66100 | C87000 to C87999 |
| Silicon Red Brass | C69400 to C69710 | C87300 to C87900 |
| Copper Nickel | C70100 to C72950 | C96200 to C96900 |
| Nickel Silver | C73500 to C79900 | C97300 to C97800 |

**Copper** in its pure, unalloyed state is soft, provides high electrical and thermal conductivity and has excellent corrosion resistance. There are various grades of unalloyed copper, which differ in the amount of impurities they contain. Oxygen-free coppers are used specifically in applications requiring high conductivity and exceptional ductility.

**Brasses** are alloys made from copper and zinc, they exhibit good strength and ductility and are easily cold worked, properties which improve with increased zinc content up to 35%. Brass coloration ranges from red to golden yellow, depending on the amount of zinc the alloy contains. Gilding metal, Commercial bronze, Jewelry bronze, Red brass and cartridge brass are common names given to brass alloys with specific zinc contents. Brasses containing between 32% and 39% zinc exhibit excellent hot working characteristics but limited cold workability.

Brasses containing more than 39% zinc, such as Muntz Metal, have high strength and lower ductility at room temperature than alloys with less zinc. Brasses are known for their ease of fabrication by drawing, high cold-worked strength and corrosion resistance.

Brasses are routinely blanked, coined, drawn and pierced to produce springs, fire extinguishers, jewelry, radiator cores, lamp fixtures, ammunition, flexible hose and the base for gold plate. Brasses have excellent castability. Cast brasses are used as plumbing fixtures, decorative hardware, architectural trim, low pressure valves, gears and bearings.

**Tin Brasses** are alloys made from copper, zinc (2% to 40%) and tin (0.2% to 3%). This family of alloys includes admiralty brasses, naval brasses and free-machining tin brasses. These alloys are used to make high-strength fasteners, electrical connectors, springs, corrosion resistant mechanical products, marine hardware, pump shafts, and corrosion-resistant screw machine parts. They provide increased corrosion resistance, lower sensitivity to dezincification and higher strength compared with straight brasses. They possess good hot forgeability and good cold formability. These materials have moderate strength, high atmospheric and aqueous corrosion resistance and excellent electrical conductivity.

**Silicon Bronzes** are part of the subgroup of high-strength brasses. They contain less than 20% zinc and up to 6% silicon and are solid solution strengthened. Silicon red brasses are used for valve stems where corrosion resistance and high strength are critical. Included in this category are the silicon red bronzes, which are similar to silicon red brasses except for their very low concentrations of zinc. They are used to make bearings, gears and intricately shaped pump and valve components.

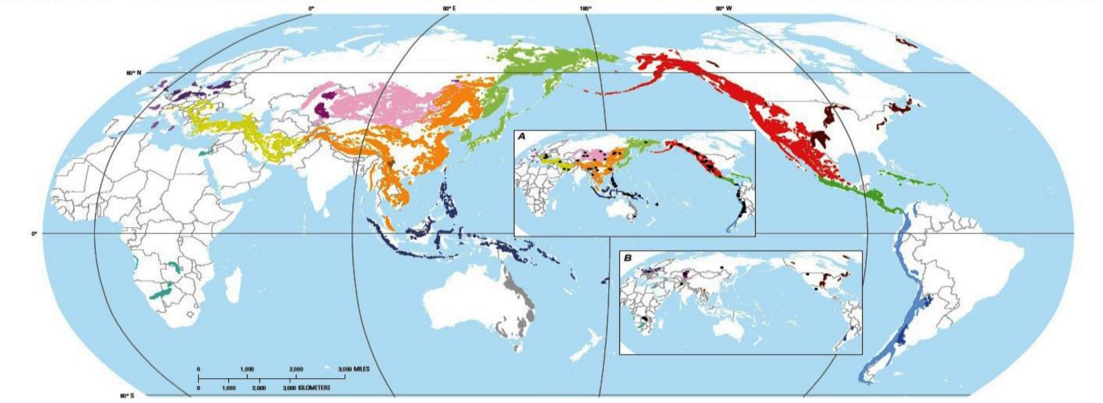
**Nickel Silvers**, also called nickel brasses, are alloys containing copper, nickel, and zinc. Though they do not contain silver, they have an attractive silver luster, moderately high strength and good corrosion resistance. They are used to make food and beverage handling equipment, decorative hardware, electroplated tableware, optical and photographic equipment and musical instruments.

**Copper Nickel** alloys contain anywhere from 2% to 30% nickel, are highly corrosion-resistant and thermally stable. The addition of iron, chromium, niobium and/or manganese can improve their strength and corrosion resistance. They are virtually immune to stress corrosion cracking and exhibit high oxidation resistance in steam and moist air. The higher nickel alloys are well known for their corrosion resistance in sea water as well as resistance to marine bio fouling. They are used to make electrical and electronic products, tubes for condensers in ships, on offshore platforms and in power plants, and various other marine products including valves, pumps, fittings and sheathing for ship hulls.

**Phosphor Bronzes**, or tin bronzes as they are sometimes called, contain between 0.5% and 11% tin and 0.01% to 0.35% phosphorous. Tin increases their corrosion resistance and tensile strength; phosphorous increases wear resistance and stiffness. Phosphor bronzes have superb spring qualities, high fatigue resistance, excellent formability and solder ability, and high corrosion resistance. They are used primarily for electrical products; other uses include corrosion resistant bellows, diaphragms and spring washers. [9]

## 6. COPPER SOURCES AND SUPPLY

Copper reserves amount to 690 million tons (US Geological Survey, 2014). Copper resources are estimated to exceed 5,000 million tons (USGS, 2014). The number does not include vast copper deposits found in deep sea nodules and submarine massive sulfides. Current and future exploration opportunities will increase both reserves and known resources. According to USGS data, since 1950 there has always been, on average, 40 years of copper reserves and over 200 years of resources left. [10]



| **Western Europe** | | **Eastern Europe and South West of Asia** | | **North General Asia** | | **North East Asia** | | **Central America and the Carabians** | |
|---|---|---|---|---|---|---|---|---|---|
| 🟪 | Porphyry | 🟩 | Porphyry | 🟪 | Porphyry | 🟩 | Porphyry North America | 🟩 | Porphyry South America |
| ⬛ | Sediment- hosted stratabound Africa middle east | 🟩 | Sediment- hosted stratabound South West Asia | 🟥 | Sediment-hosted stratabound South Central Asia | 🟧 | Porphyry | 🟦 | Porphyry |
| 🟦 | Sediment hosted stratabound | 🟦 | Porphyry Australia | 🟧 | Porphyry | 🟫 | Sediment- hosted stratabound South Central Asia | 🟦 | Sediment- hosted stratabound |
| | | ⬜ | Porphyry | 🟫 | Sediment- hosted stratabound | | | | |

Figure 11. Locations of tracts assessed for this study, grouped by region and deposit type, Insert maps show identified deposits containing more than 2 million metric tons copper (black dots); A. porphyry copper, B: sediment-hosted stratabound copper

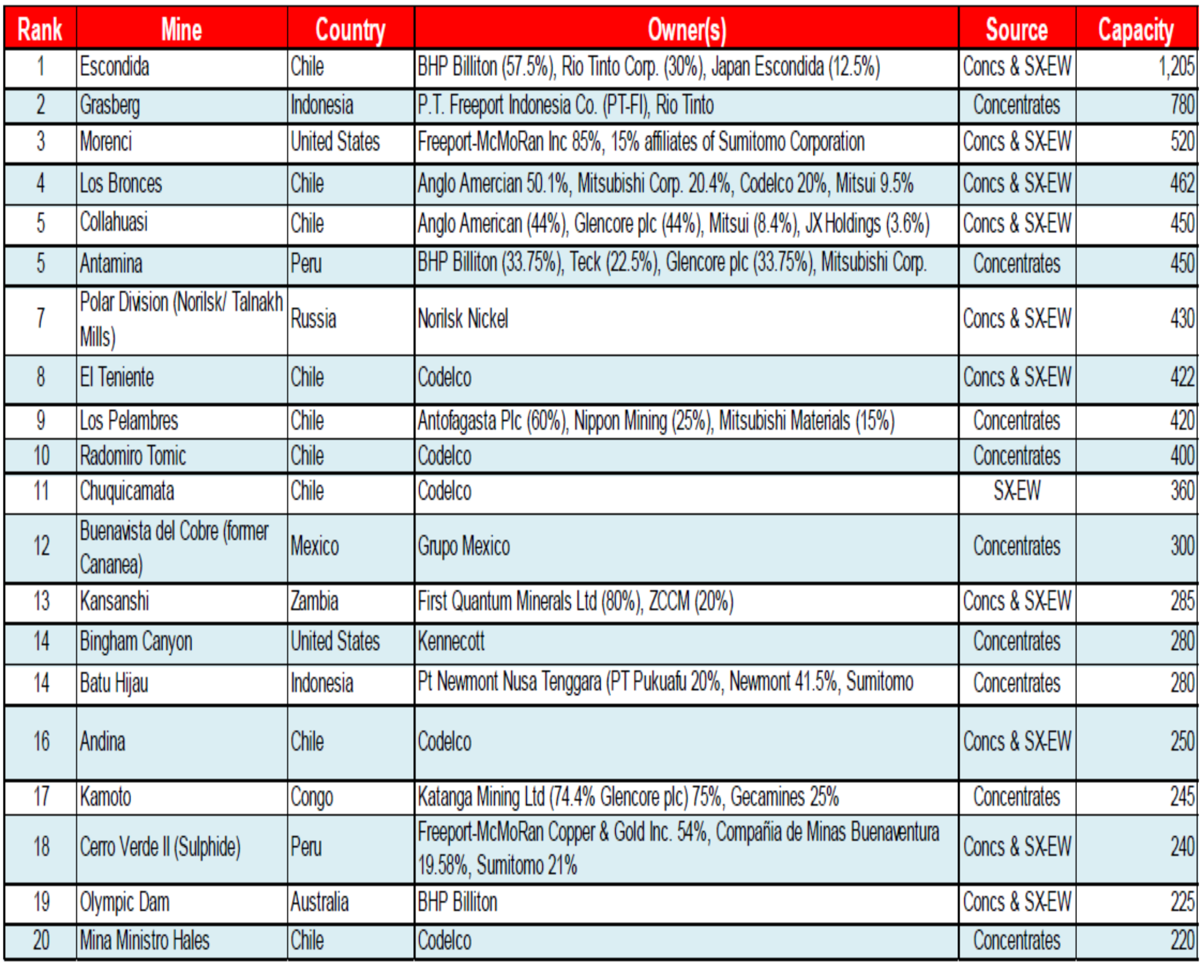
Source: U.S. Geological Survey

## 6.1. MAIN COPPER MINES IN THE WORLD

Table 3: Top 20 Copper Mines by Capacity (basis 2015)

Thousand metric tons copper

Source: ICSG Directory of Copper Mines and Plants – July 2015



| Rank | Mine | Country | Owner(s) | Source | Capacity |
|---|---|---|---|---|---|
| 1 | Escondida | Chile | BHP Billiton (57.5%), Rio Tinto Corp. (30%), Japan Escondida (12.5%) | Concs & SX-EW | 1,205 |
| 2 | Grasberg | Indonesia | P.T. Freeport Indonesia Co. (PT-FI), Rio Tinto | Concentrates | 780 |
| 3 | Morenci | United States | Freeport-McMoRan Inc 85%, 15% affiliates of Sumitomo Corporation | Concs & SX-EW | 520 |
| 4 | Los Bronces | Chile | Anglo American 50.1%, Mitsubishi Corp. 20.4%, Codelco 20%, Mitsui 9.5% | Concs & SX-EW | 462 |
| 5 | Collahuasi | Chile | Anglo American (44%), Glencore plc (44%), Mitsui (8.4%), JX Holdings (3.6%) | Concs & SX-EW | 450 |
| 5 | Antamina | Peru | BHP Billiton (33.75%), Teck (22.5%), Glencore plc (33.75%), Mitsubishi Corp. | Concentrates | 450 |
| 7 | Polar Division (Norilsk/ Talnakh Mills) | Russia | Norilsk Nickel | Concs & SX-EW | 430 |
| 8 | El Teniente | Chile | Codelco | Concs & SX-EW | 422 |
| 9 | Los Pelambres | Chile | Antofagasta Plc (60%), Nippon Mining (25%), Mitsubishi Materials (15%) | Concentrates | 420 |
| 10 | Radomiro Tomic | Chile | Codelco | Concentrates | 400 |
| 11 | Chuquicamata | Chile | Codelco | SX-EW | 360 |
| 12 | Buenavista del Cobre (former Cananea) | Mexico | Grupo Mexico | Concentrates | 300 |
| 13 | Kansanshi | Zambia | First Quantum Minerals Ltd (80%), ZCCM (20%) | Concs & SX-EW | 285 |
| 14 | Bingham Canyon | United States | Kennecott | Concentrates | 280 |
| 14 | Batu Hijau | Indonesia | Pt Newmont Nusa Tenggara (PT Pukuafu 20%, Newmont 41.5%, Sumitomo | Concentrates | 280 |
| 16 | Andina | Chile | Codelco | Concs & SX-EW | 250 |
| 17 | Kamoto | Congo | Katanga Mining Ltd (74.4% Glencore plc) 75%, Gecamines 25% | Concentrates | 245 |
| 18 | Cerro Verde II (Sulphide) | Peru | Freeport-McMoRan Copper & Gold Inc. 54%, Compañia de Minas Buenaventura 19.58%, Sumitomo 21% | Concs & SX-EW | 240 |
| 19 | Olympic Dam | Australia | BHP Billiton | Concs & SX-EW | 225 |
| 20 | Mina Ministro Hales | Chile | Codelco | Concentrates | 220 |

### 6.1.1. ESCONDIDA, CHILE

The Escondida copper-gold-silver mine is located in the arid, northern Atacama Desert of Chile about 160km southeast the port of Antofagasta, at an elevation of 3,050m above sea level. The mine is a joint venture between BHP-Billiton (57.5%), Rio Tinto (30%), a Japanese consortium (10%) and the International Finance Corporation (2.5%). It came on-stream in late 1990 and its capacity has since been increased by phased expansions to the current level of 230,000t/d ore throughput. The mine employs around 2,200 people.

Figure 12. Escondida Mine

Source: mining.com

Production at the mine was cut back during the period 2003 on account of the weak world market conditions for copper. The partners in the project decided to mine lower-grade ores while maintaining the concentrator throughput, thus reducing the impact on per-ton-treated costs. Output was subsequently ramped up again, and during 2004 the mine handled 377Mt of ore and waste, and processed 82.4Mt of sulphide ore grading 1.51% copper (up from 70.3Mt at 1.43% copper in 2003).

During the year ending June 2006, the mine handled 368.3Mt of ore and waste and processed 87.7Mt of sulphide ore grading 1.61% copper. Total mill output was 1,207,100 tons. Payable copper production was 1.17Mt of copper, electrowon copper cathode output was 116,300 tons, payable gold in concentrate was 139,000oz and payable silver in concentrate was 5.9Moz.

In 2007, the copper mine boosted output by 18.2% after producing 1.245 million tons of copper contained in concrete and 238,357 tons in cathodes. However, during the first nine months of 2008, Escondida experienced a 10.4% production rate compared to the same period a year ago. Escondia's production is recovering however with new resources discovered at Chimborazo and through further brownfield exploration. Copper production is expected to be over 1.3 million tons by 2015. [26]

### 6.1.2. CANANEA, MEXICO

The Cananea mine in Sonora is Mexico's largest open pit copper mine, one of the largest in the world and – having opened in 1899 – one of the oldest on the North American continent.

No actual mining has taken place since June 2007, when miners went on strike citing unsafe working conditions and poor worker health. The ongoing legal disputes have cost the mine's owner, Grupo Mexico, more than $3.2bn.

A breakthrough was made in February 2010 when Mexico's federal court ruled in the company's favor, giving Grupo Mexico permission to terminate the contracts of the striking miners and hire new staff to resume production.

Figure 13. Cananea Copper Mine, Sonora

Source: NASA Earth Observatory, March 2008

In April 2010, several striking miners responded that they would destroy the mine site if the company tried to end their employment. In June 2010, the Mexican police removed all striking miners from the site, allowing Grupo Mexico to begin diagnostics and repair works. In September 2010, fresh clashes erupted at the site between the dismissed union workers and contract workers. Two contract workers were seriously injured. Ore from Cananea mine is extracted using conventional open pit mining techniques, and then refined further at an on-site concentrator. Ore with more than the mill cut-off grade (0.34%) is reduced to approximately half an inch in large rotating crushers. It is then ground to a fine powder in the ball and bar mills.

This leaves a finely ground powder, which is agitated in a mixture of water and reagents before it is delivered to the flotation cells. Air is pumped into this mix, causing it to froth and the copper mineral to float. Copper concentrates with an average 26.26% copper value are produced once the recovered copper is filtered and dried. It is then transported to the smelter at La Caridad by rail. [26]

### 6.1.3. COLLAHUASI, CHILE

Collahuasi copper mine is situated in northern Chile, about 180km southeast of the port of Iquique, at an altitude of 4,000m. In 2012 it was announced that 25.895 million ton of Copper can be extracted from this mine. In 2012, 282,069 ton copper were extracted from this mine which was 5.1 % of Chile’s Copper production. The mine is 44%-owned to Anglo American 44% to Xtrata and 12% to a Japanese consortium (12%) leading by Mitsui Mining & Smelting Co. Ltd.

Figure 14. Collahuasi copper mine

Source: golder.com

Lying in an area of historical copper mining, the deposit was outlined in 1991 after exploration by Shell, Chevron and Falconbridge in the late 1980s. The mine was commissioned in April 1999 at a cost of US$1.76bn. During 2004, the project partners completed a $584m expansion program at the mine, giving it a long-term capacity of 500,000 ton per year Copper. [27]

### 6.1.4. ANDINA, CHILE

Andina copper mine is located in 80 km northeast of Santiago, Chile in the northern part of the country. The mine is the world's fourth largest mine in terms of reserves. Early in 2013, it was estimated that 18.8 million tons of pure copper (2551 million tons of copper ore grade 0.74%) can be extracted from the mine. Codelco (Corporacion Nacional del Cobre de Chile) is now the owner of Andina and this company is now the largest producer of world's Copper.

Figure 15. Andina copper mine

Source: mining-technology.com

Andina mine complex includes an underground mine called Rio Blanco and an open pit mine called Sur Sur. In 2012 the mine 249,861 tons of copper and molybdenum was extracted from the mine. [27]

### 6.1.5. TOQUEPALA, PERU

Toquepala copper mine is located in 870 kilometers of Lima, capital of Peru, and is in fifth place among the largest mines of the world in terms of mineral reserves. In a comprehensive report released in December 2012, it was predicted that 17.65 million ton Copper existed in the mine. Southern Copper Corporation, a subsidiary of Grupo Mexico is the owner of the mine. In the same year, Toquepala produced about 152,000 tons of copper ore which included 120,000 tons concentrate and 32,000 tons copper cathodes.

Figure 16. Toquepala copper mine

Source: mining-technology.com

Impure Copper ore extracted from mines is purified to some extent in the beneficiation plant located in courtyard of the mine. Concentrate obtained in this step is sent by rail to Ello smelter to be refined. The production of mine is 56,000 ton per year of copper cathode. [27]

### 6.1.6. EL TIENIENTE, CHILE

El Tieniente copper mine is the world sixth largest copper mine in terms of reserves, and is located in 80 kilometers from Santiago and the Andes Mountains in Chile. The mine is considered as the largest underground copper mine in the world. At the beginning of 2013, experts report estimated that 15.2 million tons of copper can be extracted from this mine (1538 tons of ore with 0.99 percent purity).

Figure 17. El Tieniente copper mine

Source: mining-technology.com

Mining operations started in El Tieniente in 1904. The mine is also under the supervision of Codelco. El Tieniente copper products, includes copper cathode and pure lingat. In 2012 417,244 tons of copper were extracted from El Tieniente. El Tieniente development of mining projects will be completed in 2017 and will take 50 years that reserves to be finished. [27]

### 6.1.7. CERRO VERDE, PERU

Cerro Verde Copper Mine is located 32km south-west of Arequipa in Peru. The mining concession spreads across approximately 157,007 acres (63,538ha), plus 24 acres of owned property and 79 acres of rights-of-way outside the concession region. It is the second biggest copper mine in Peru, based on contained reserves.

Figure 18. Cerro Verde Copper Mine

Source: yelp.com

Freeport McMoRan, through its subsidiary Cyprus Climax Metals, owns 53.56% stake in the mine and SMM Cerro Verde Netherlands, a subsidiary of Sumitomo Metal Mining, holds 21%, while Compania de Minas Buenaventura and others have 19.58% and 5.86% stake respectively.

Cerro Verde has been in operation since 1976, and became part of Freeport-McMoRan's mining portfolio in 2007. Freeport-McMoRan Copper & Gold, which operates the mine, announced plans in 2011 to triple the treatment capacity at Cerro Verde. The company received important permits for the proposed expansion and commenced construction in 2013.

A copper sale agreement has been signed with Sumitomo Metal Mining and a molybdenum sale contract with Climax Molybdenum Marketing. [27]

### 6.1.8. RADOMIRO TOMIC, CHILE

Radomiro Tomic is located in Atacama desert in North of Chile and is the eighth great mine of the world from copper reserve point of view. In 2013 it was forecasted that 12.1 million ton Copper can be extracted from this mine. Development was approved in 1995, started in 1996 and was essentially completed in 1997. This is the first mine which was owned by Codelco state owned company and in 2012, 427,791 ton Copper and molybdenum were extracted from the mine.

Figure 19. Radomiro Tomic Copper Mine

Source: clas.berkeley.edu

The development project of the operation of Radomiro tomic Copper Sulfide was finished in June 2010 with 370 million dollar investment. In this phase one crushing machine was installed in mine courtyard which crushed 100,000 ton of ores daily and send it to beneficiation plant in Chokikamata. [27]

### 6.1.9. LOS BRONCES, CHILE

Los Bronces mine is located in 65 km of Santiago, in Chile's Andean highlands and is the world's ninth largest copper mine. In december 2012 it was identified that 11.13 million tons can be mined from open pit mine. In 2012, 365,000 tons of Copper were extracted. Anglo American holding company posses 50.1% of this mine share and is the biggest shareholder of the mine and has the operation responsibility of the mine. Japan Mitsobishi has 20.4% of the shares. Codelco and Mitsui are the owner of 29.5% of the shareholders. Los Bronces is one of the oldest mines of America continent which has been extracted from 150 years ago and it is estimated that after thirty years its reserves will be finished.

Figure 20. Los Bronces Copper Mine

Source: mining-technology.com

The development projects for extraction were finished in 2012and extraction capacity reached to its maximum. The product of this mine is concentrate and Cothodes.

To obtain higher purity copper, ores are grounded in the courtyard and is sent through 52 kms pipeline in a solution form to Tortolas. Lower grade ores are used for cathode production by flotation and electrowinning. [27]

### 6.1.10. GRASBERG, INDONESIA

Grasberg in Papoa Province of Indonesia is the tenth largest mine in the world from Copper reserves point of view. Between ten great mine of the world, it is the only non-American mine which has been located in the tenth rank. This mine consists of two main parts of open pit and undergrounds mine and was identified in December 2012that production of this mine reached to 315.246 tons Copper. One of the other main points of this mine is that the greatest gold reserve of the world is located in mine. The Grasberg mine was identified in 1988 and mining in open pit part began in 1990. Mining in this part will continue till 2016.

Figure 21. Grasberg Copper Mine

Source: mining-technology.com

PTFI Company is the owner of 90.64 % of the mines and is responsible for its operation. Indonesia government has the remained part of the shares. Indonesia Freeport which is a sub company of Freeport McMoran works in this mines. [27]

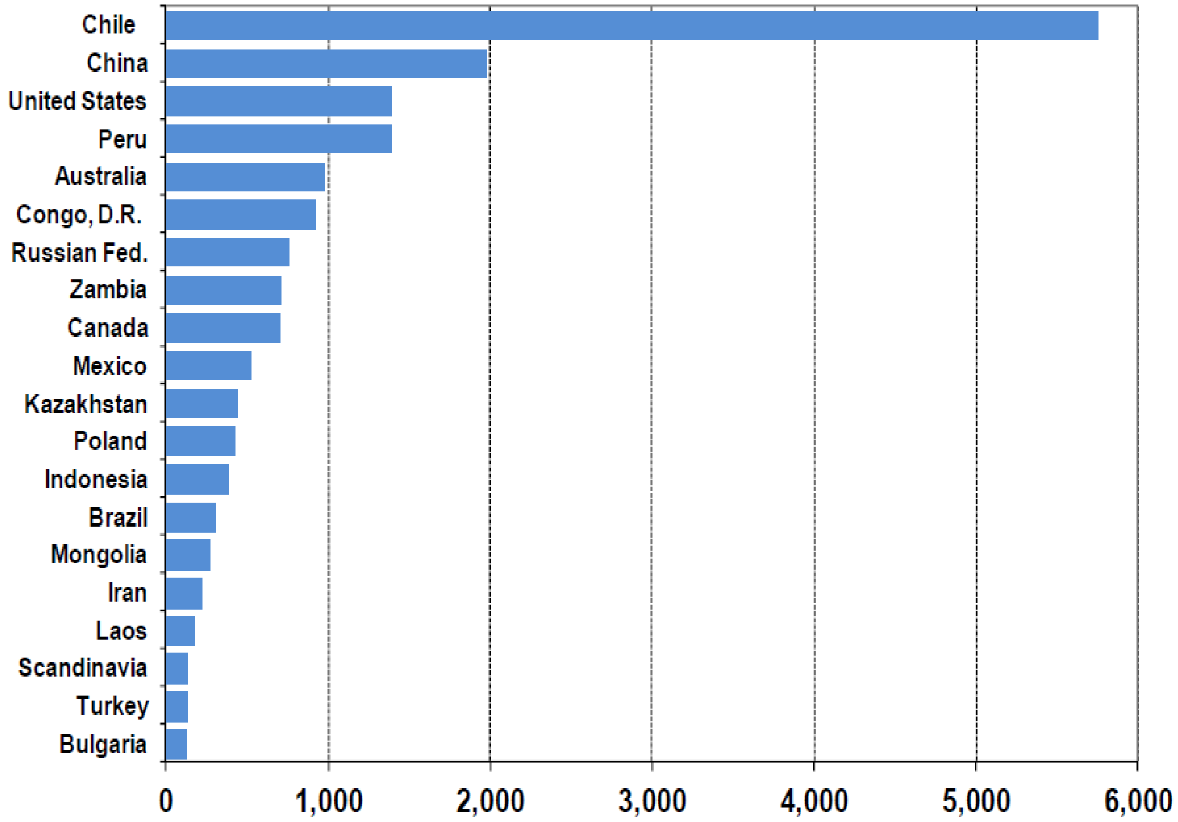


Figure. 22: Copper Mine Production by Country: Top 20 Countries in 2014

(Thousand metric tons)

Source: ICSG

## 6.2. IRAN COPPER SOURCES

Iran's mineral wealth, in addition to oil and gas, includes chromite, lead, zinc, copper, coal, gold, tin, iron, manganese, ferrous oxide, and tungsten. Iran possesses large copper resources contained in porphyry deposits, including the world-class Sarcheshmeh and Sungun mines reserves, or about 4% of the world's total (17th largest reserve globally). According to investigation rendered, Iran is located on world copper belt starting from South East to North West of Iran and Azarbaijan. Iran has the world's second-largest Copper ore production accounts for 75% of the total production in the Middle East.

Mining in Iran has taken place since about 5,000 B.C. Anarak, for example, was one of the earliest mining regions the world. Copper artifacts discovered during various studies and at sites of primitive smelting furnaces, still visible today, confirm that Iran has been mining and smelting copper for centuries. During the 1960s and 1970s, geologic surveys by the Iranian government led to the systematic recording of known deposits, as well as the search for new ones. As a result, about 250 copper occurrences and several potentially viable projects were recognized, including the Darreh-Zerreshk and Ali Abad porphyry systems. At the same time, prospecting and drilling was underway at Sarcheshmeh. Sungun deposit was discovered in the mid-1970s when fluid inclusion analysis suggested the presence of mineralization similar to that found at other world's large copper deposits. In 1972, Sarcheshmeh Copper Mines Joint Stock Co. of Kerman was established, which in 1976 was renamed as the National Iranian Copper Industries Company to encompass all copper mining operations throughout Iran. By 1977, about half the country had been surveyed from the air, but less than one-fifth had been explored on the ground.

Following the revolution in 1979 and the 1982 Iran-Iraq War, Australian, Canadian, French, and Yugoslavian mining companies joined the Geological Survey of Iran in the exploration effort. Since 1998, the Iranian government has allowed foreign investment in mineral exploration joint ventures. For its economic development plan 2000–2005, the government proposed to privatize 40 mineral industry companies affiliated with the Ministry of Industry and Mines, having already divested itself of more than 90 percent of its mineral enterprises. In 2009, Kazakhmys, Kazakhstan's largest mining and energy group and international natural resources company, announced that it would expand its activities in Iran and assist the country in projects to discover gold and copper deposits.

Over the past 10 years, the National Iranian Copper Industries Company has led extensive exploration efforts for porphyry copper deposits, particularly in the northwestern Arasbaran and southeastern Kerman regions of the country. Sarcheshmeh and Meiduk in Kerman Province and Sungun in eastern Azerbaijan Province are the three largest porphyry copper mines in the country. Several other porphyry deposits are in development or have begun operations, including Haft Cheshmeh and Masjed Daghi in the northwestern part and Darrehzar, Chah-Firuzeh, Taft (Darreh-Zerreshk and Ali-Abad), and Dar Alu in the southeastern part of the country. More recent exploration efforts have also identified porphyry copper prospects in the Yazd, central-eastern Lut eastern Sistan, and northeastern Khorasan regions of the country. In contrast, limited porphyry-related exploration information available for the northern Alborz, western Sanandaj-Sirjan, central Iranian, and Makran regions of the country suggest that these regions may be comparatively underexplored for porphyry copper deposits.

### 6.2.1. GREATER CAUCASUS AND NORTHERN IRAN

In the Greater Caucasus, paleogeographic reconstructions indicate that the region emerged above sea level only after the middle Miocene (13–14 Ma). Since then, the region has grown into a major mountain range formed by a doubly vergent fold-and-thrust belt. Late Miocene (11–10 Ma) to middle-late Pliocene (3.4–1.8 Ma) compression and uplift were predominantly accommodated by west-northwest trending reverse faults. A shift from a compressional to a transpressional regime over time resulted in northwest-southeast and thrust-parallel west-northwest oblique slip components, and associated north-northeast transtensional faults with left-lateral components along the main shortening direction.

The compressional regime continues across northern Iran, where folding and thrusting in the Talysh and Alborz regions are a product of the far-field deformation associated with the middle Miocene collision between the Arabian Platform and Eurasia. Thrusting and folding dominate along the flanks of the Alborz mountain range. Thrusts dip north in the southern flanks, and south in the northern flanks of the range, creating a flower structure. Deformation is accompanied by range-parallel steeply dipping sinistral strike-slip faults that are mainly located within the range interior, although the sense of strike-slip offset was just the opposite before 5 Ma. Faults with normal separation do occur and bound pull-apart basins along strike-slip faults. Latest Miocene to Holocene volcanic edifices preferentially occupy these structural zones, and where they exhibit permissive intermediate to felsic composition, they define the Pliocene-Quaternary–Postcollisional sub-tract. One deeply exhumed porphyry copper prospect is known in this part of the sub-tract.

In the Alborz range, as in the Greater Caucasus, thermochronological studies indicate rapid uplift and several kilometers of exhumation since 6 Ma. This age coincides with subsidence in the South Caspian Sea, where the larger fraction of the 10-km-thick sedimentary section there has been deposited since ~6 Ma.

The Kopet Dagh Terrane of northeastern Iran, like the Alborz Terrane, displays partitioning of the overall convergence into reverse and strike-slip components. In the western part of the Kopet Dagh Terrane, current shortening is accommodated by south-vergent west-southwest thrusts and thrust-parallel left-lateral strike-slip faults. In the eastern part of the Kopet Dagh Terrane, south-vergent east-southeast thrusts and right-lateral strike-slip faults parallel the Apsheron Sill that projects from the Caspian Sea into this region.

Structural elements in the Talysh, Alborz, and Kopet Dagh Terranes have not only been influenced by the far-field effects of the Arabian Platform-Eurasia collision to the south, but by their interaction with the adjacent South Caspian Sea Terrane to the north. Geophysical data suggest that South Caspian Sea Terrane is in the early stages of subducting north and possibly west under the Apsheron Sill and the Talysh regions, respectively. Thus, the South Caspian Sea Terrane appears to be moving westward relative to the adjacent terranes of northern Iran, resulting in thrusting in the Talysh Terrane to the west, thrusting and left-lateral faulting in the Alborz and western Kopet Dagh Terranes to the south, and thrusting and right-lateral faulting along the on-land projection of the Apsheron Sill in the eastern Kopet Dagh Terrane to the east. Latest Miocene to Holocene volcanism preferentially occupies these structural zones, and where it shows permissive intermediate to felsic composition, it defines the Pliocene-Quaternary–Postcollisional sub-tract. No porphyry copper prospects have positively been identified in this part of the sub-tract.

### 6.2.2. EASTERN AND CENTRAl_EASTERN IRAN

In the Sistan suture zone of eastern Iran, east-northeast-directed convergence and final collision between the Lut Terrane of Iran on the west and the Farah Terrane of Afghanistan on the east occurred between the middle Eocene and middle Miocene. Since then, continued compression is being accommodated by north-northwest- and northeast-trending en echelon dextral faults that are part of the greater Nehbandan Fault system. However, the major relative motions appear to be occurring along the Nehbandan fault proper.

In the Lut Terrane of central-eastern Iran, the neotectonic structure consists of a series of parallel north-northwest right lateral faults represented by the Nayband and

Nehbandan transpressional systems that bound the Lut Terrane to the east and west, respectively. As in the Sistan suture zone, these structures are accommodating the ongoing east-northeast-directed horizontal shortening in the region, which is generally composed of dextral northeast and sinistral northwest faults.

Latest Miocene to Holocene volcanic-dominated igneous rocks preferentially occupy structural zones in eastern and central Iran. Where they show permissive intermediate to felsic composition, they define the Pliocene-Quaternary–Postcollisional sub-tract. No porphyry copper prospects have positively been identified in this part of the sub-tract.

### 6.2.3. CENTRAL AND SOUTHEASTERN IRAN

The diachronous northwest-to-southeast oblique collision between the Arabian Platform and the Eurasian margin occurred about the late Oligocene (~27 Ma) in the northwestern part, about the middle Miocene (~16 Ma) in the central part, and about the late Miocene (~7 Ma) in the southeastern part of Iran. From northwestern to southeastern Iran, collision along the Bitlis-Zagros Suture triggered widespread crustal shortening and thickening, generating uplift and a fold-and-thrust belt in the Sanandaj-Sirjan and Central Iranian Terranes. Evidence of far-field deformation is also present to the north in the Talysh, Alborz, and Kopet Dagh Terranes. Since the early Pliocene, folding associated with the south-vergent thrusting of the Sanandaj-Sirjan Terrane over the Arabian Platform has also propagated to the southwest across the Bitlis-Zagros Suture forming the present-day Zagros Folded Belt. To the northeast of the Bitlis-Zagros Suture, north-vergent thrusts and northwest-southeast en echelon strike-slip faults occur well into the Central Iranian Terrane. Deformation is most intense along the Bitlis-Zagros Thrust, which consists of a combination of thrusting followed by Pliocene-Holocene right-lateral strike-slip movements. Strike-slip displacements are estimated at between 50 and 70 km over the past 3–5 million years (m.y.). This compressional to transpressional regime continues today.

Large volcanic edifices of latest Miocene to Holocene age occur along the Urumieh-Dokhtar Magmatic Belt in this region. Permissive intermediate to felsic igneous rocks associated with this event define the Pliocene-Quaternary–Postcollisional sub-tract. One known porphyry copper prospect of Latest Miocene to Holocene age is included in this part of the sub-tract. However, as many as five other porphyry and porphyry-related acid-sulfate systems are possibly also related to this postcollisional magmatic event.

### 6.2.4. SOUTHEASTERN IRAN AND SOUTHWESTERN PAKISTAN

The subduction-related Bazman-Taftan-Koh-i-Sultan continental arc of southeastern Iran, western Pakistan, and southern Afghanistan initiated in the Miocene-Pliocene as a result of southward migration and flattening of the subducted slab, now located along the Makran Trench. Large early Pliocene to Holocene volcanic edifices associated with this volcano-plutonic event define the Pliocene-Quaternary–Bazman sub-tract. The Bazman-Taftan-Koh-i-Sultan Arc hosts numerous epithermal systems, some of which are known to be porphyry-related. This sub-tract includes two positively identified porphyry prospects reserves of copper and accounts for approximately 2,600 million tons of copper [11]

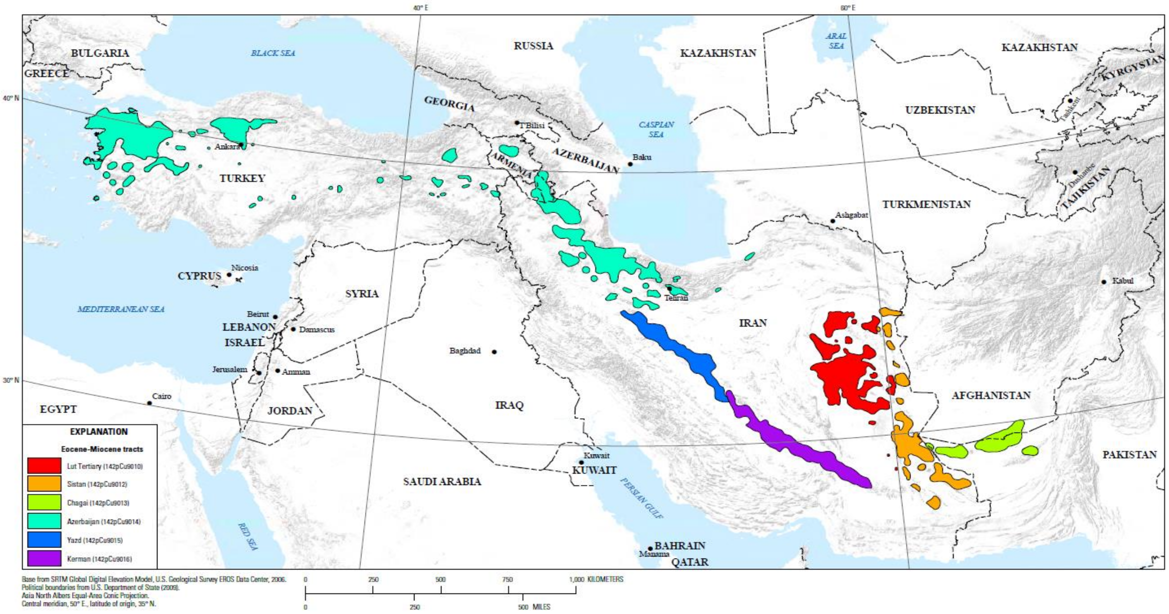
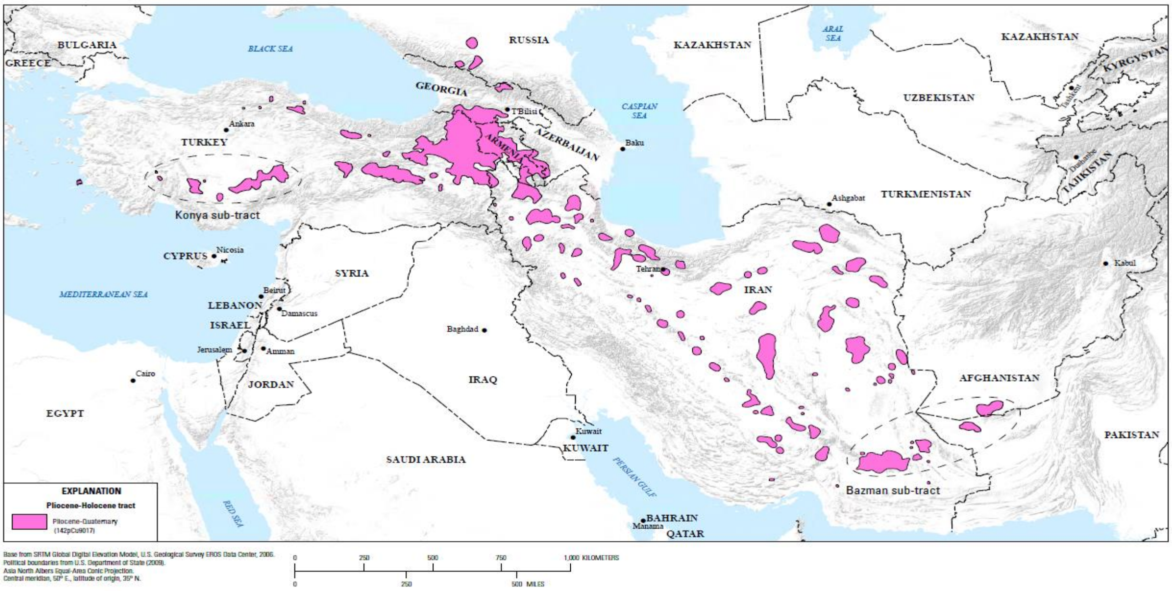


Figure 23. Eocene to Miocene permissive tracts for porphyry copper deposits in the Tethys region of western and southern Asia.

Source: pubs.usgs.gov

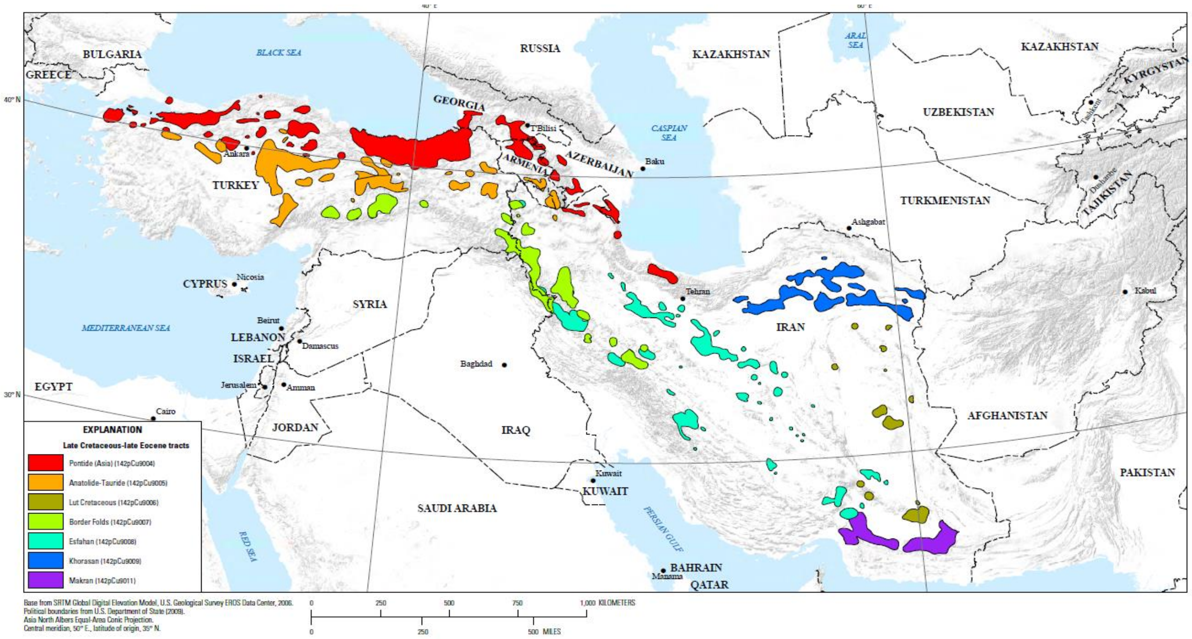


Base from SRTM Global Digital Elevation Model, U.S. Geological Survey EROS Data Center, 2006.
Political boundaries from U.S. Department of State (2009).
Asia North Albers Equal-Area Conic Projection.
Central meridian, 50° E., latitude of origin, 35° N.

**Figure 8.** Pliocene to Holocene permissive tract for porphyry copper deposits in the Tethys region of western and southern Asia.

Figure 24. Porphyry Copper Assessment of the Tethys Region of Western and Southern Asia Pliocene to Holocene permissive tract for porphyry copper deposits in the Tethys region of western and southern Asia

Source: pubs.usgs.gov



Base from SRTM Global Digital Elevation Model, U.S. Geological Survey EROS Data Center, 2006.
Political boundaries from U.S. Department of State (2009).
Asia North Albers Equal-Area Conic Projection.
Central meridian, 50° E., latitude of origin, 35° N.

**Figure 6.** Late Cretaceous to late Eocene permissive tracts for porphyry copper deposits in the Tethys region of western and southern Asia.

Figure 25. Late Cretaceous to late Eocene permissive tracts for porphyry copper deposits in the Tethys region of western and southern Asia.

Source: pubs.usgs.gov

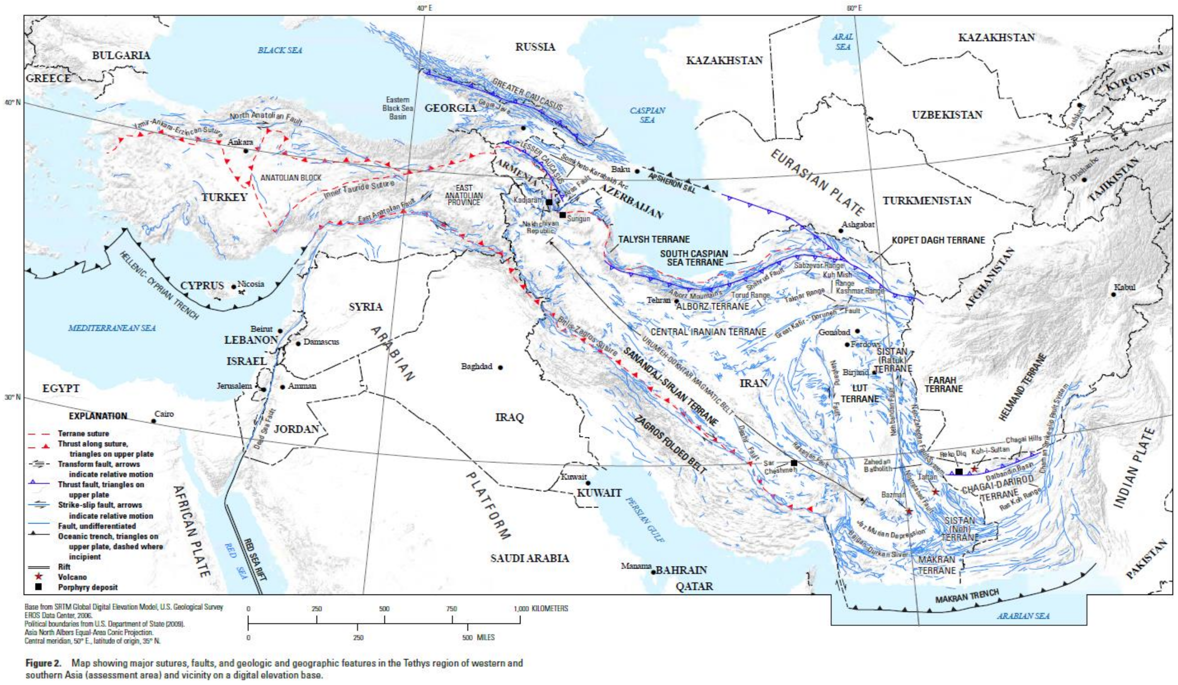


Figure 26. Map showing major sutures, faults, and geologic and geographic features in the Tethys region of western and southern Asia (assessment area) and vicinity on a digital elevation base

Source: pubs.usgs.gov

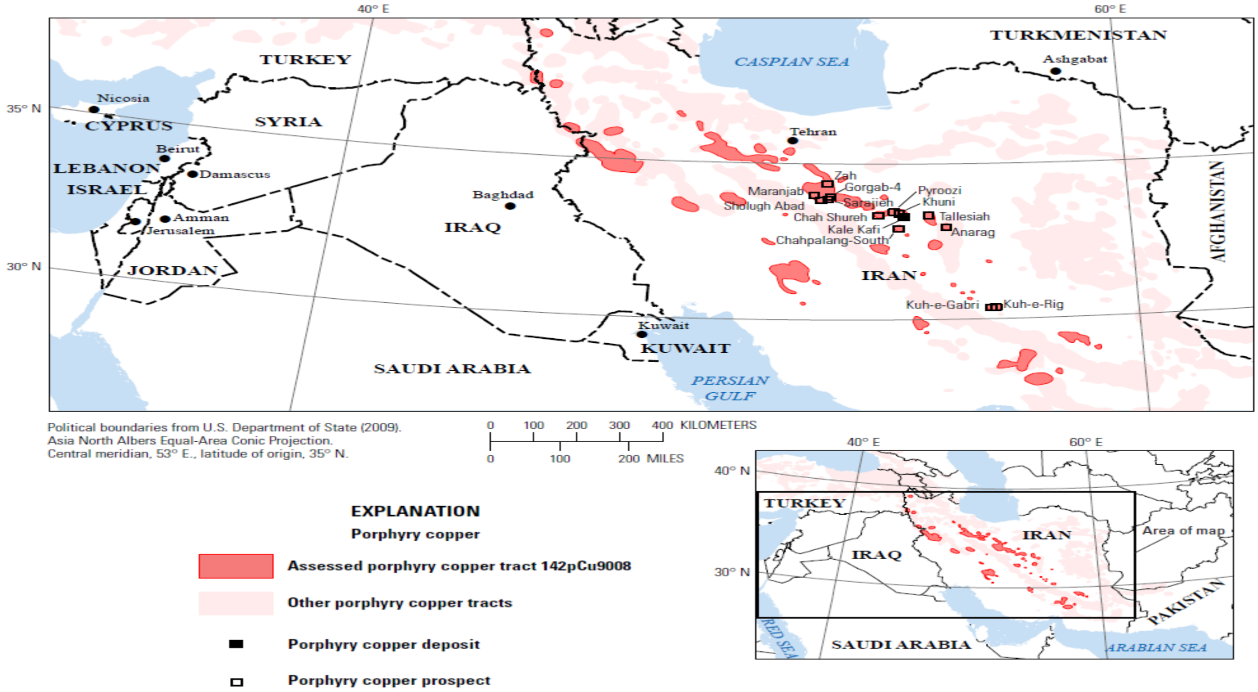
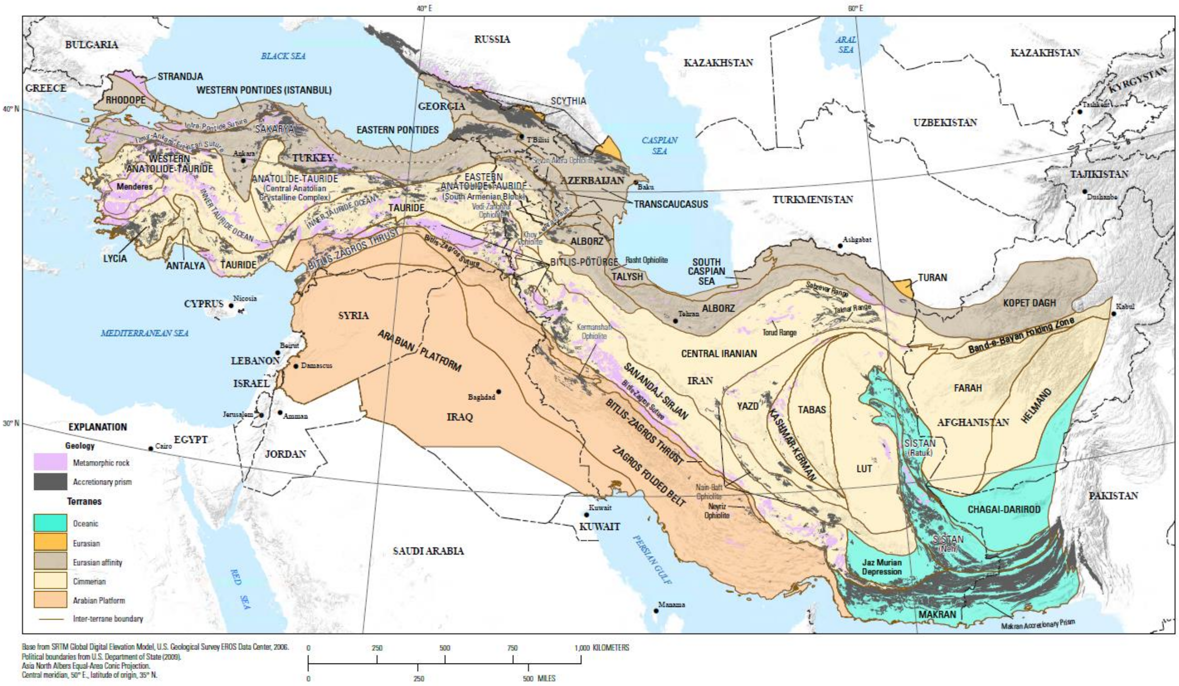


Figure 27. Map showing the location of known porphyry copper deposits and prospects for permissive tract 142pCu9008, Esfahan—Iran, Iraq, and Turkey.

Source: pubs.usgs.gov

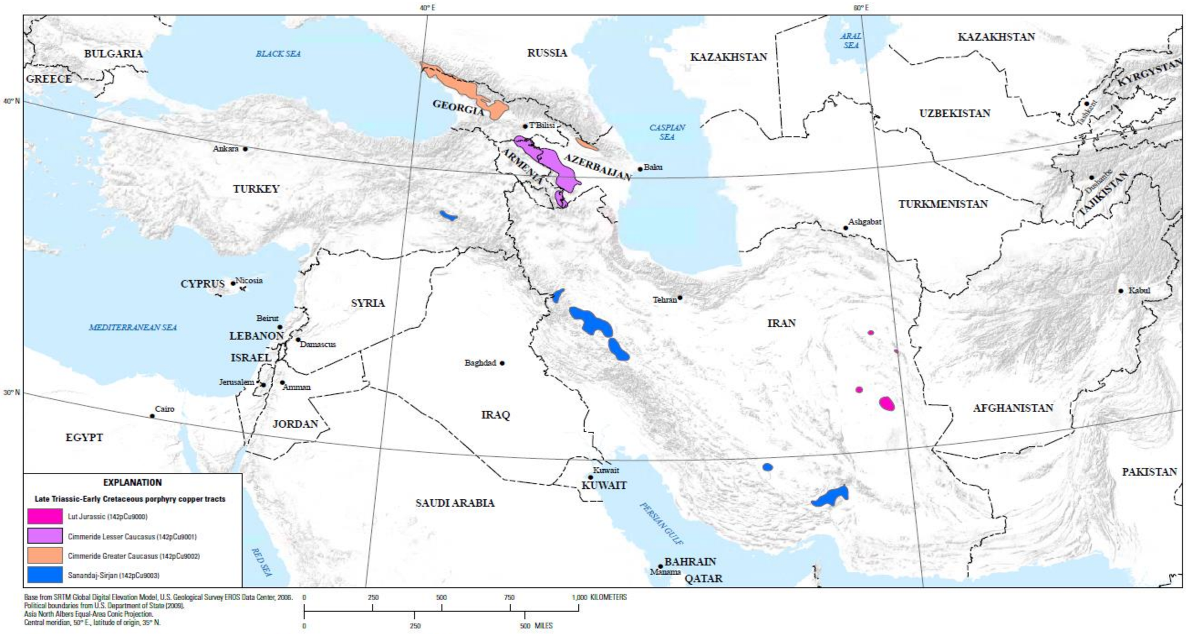


Base from SRTM Global Digital Elevation Model, U.S. Geological Survey EROS Data Center, 2006.
Political boundaries from U.S. Department of State (2009).
Asia North Albers Equal-Area Conic Projection.
Central meridian, 50° E., latitude of origin, 35° N.

**Figure 3.** Map showing tectono-stratigraphic terranes, accretionary prisms, and metamorphic belts of the Tethys region of western and southern Asia. After Abdullah and Chmyriov (1977b) and Peters and others (2011) for Afghanistan, Kazmi and Rana (1982) for Pakistan, Stöcklin (1968) for Iran, Pollastro and others (1998) for Iraq, Kaymakci and others (2010) and Yigit (2009) for Turkey, and Kekelia and others (2001) for the Caucasus. Most terrane names conform to Golonka (2004).

Figure 28. Map showing tectono-stratigraphic terranes, accretionary prisms, and metamorphic belts of the Tethys region of western and southern Asia. After Abdullah and Chmyriov (1977b) and Peters and others (2011) for Afghanistan, Kazmi and Rana (1982) for Pakistan, Stöcklin (1968) for Iran, Pollastro and others (1998) for Iraq, Kaymakci and others (2010) and Yigit (2009) for Turkey, and Kekelia and others (2001) for the Caucasus. Most terrane names conform to Golonka (2004).

Source: pubs.usgs.gov



Base from SRTM Global Digital Elevation Model, U.S. Geological Survey EROS Data Center, 2006.
Political boundaries from U.S. Department of State (2009).
Asia North Albers Equal-Area Conic Projection.
Central meridian, 50° E., latitude of origin, 35° N.

**Figure 5.** Late Triassic to Early Cretaceous permissive tracts for porphyry copper deposits in the Tethys region of western and southern Asia.

Figure 29. Late Triassic to Early Cretaceous permissive tracts for porphyry copper deposits in the Tethys region of western and southern Asia.

Source: pubs.usgs.gov

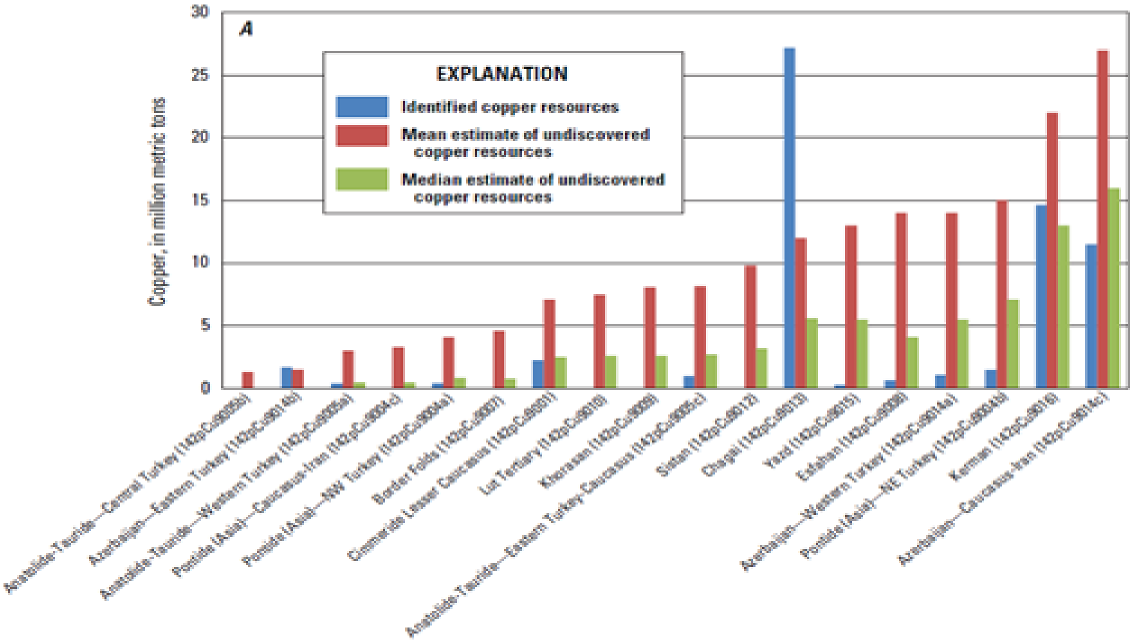


Figure 30. Summary of probabilistic assessment results by permissive tract for the Tethys region of western and southern Asia. *A*, copper. *B*, gold.

Source: pubs.usgs.gov

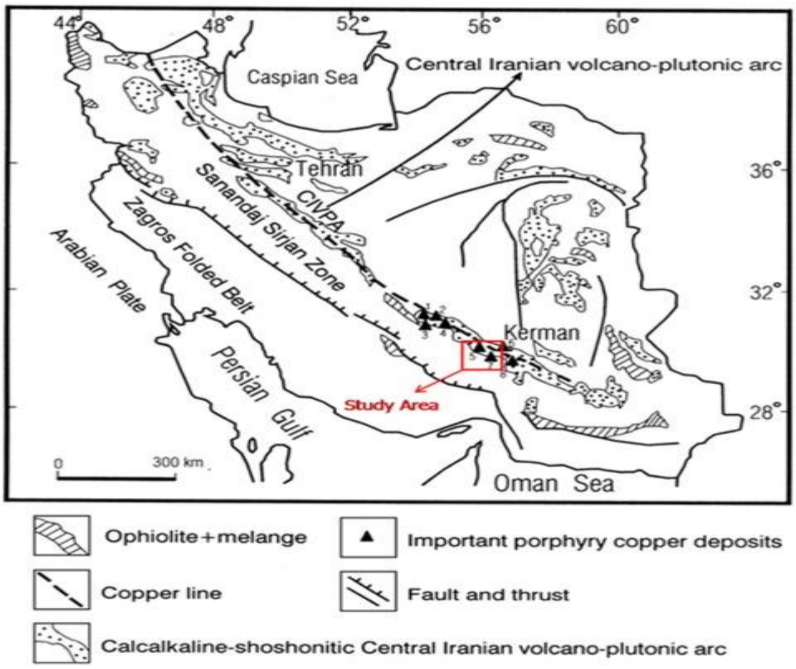


Figure 31. Copper belt of Iran. Some important porphyry copper deposits (1=Kader, 2=Gode-Kolvari, 3=Ijou, 4=Maiduk, 5=Sarcheshmeh, 6=Deh Siahan, 7=Darreh zar, 8=Chahar gonbad)

Source: Atapour and Aftabi 2007

Table 4. Copper Belt Areas
Source: Hannam and Partners, August 2015

| Belt | Commodity |
|---|---|
| Kerman | Copper |
| Khash-Nehbandan | Chromium, copper, manganese |
| Qom-Naein | Manganese, barite, copper |
| Kavir-Sabzevar | Copper, chromium, gold, iron |
| Taknar | Copper, gold, arsenic |
| Tarom-Hashtjin | Copper, iron, lead, zinc, gold |
| Maku-Khoy-Urumiyeh | Gold, mercury, copper, chromium, iron |

## 6.3. MAIN COPPER MINES OF IRAN

Table 5. Main Copper Mines in Iran

| Name | Definite and probable reserves | Average Grade(%) | Cut of Grade(%) |
|---|---|---|---|
| **Sarcheshmeh** | 1538 | 0.58 | **0.15** |
| **Miduk** | 176 | 0.61 | **0.15** |
| **Sungun** | 846 | 0.60 | **0.15** |
| **DarAlu** | 186 | 0.36 | **0.15** |
| **Chah Firuzeh** | 149 | 0.41 | **0.15** |
| **Eju** | 73.86 | 0.3 | **0.15** |
| **Darehzar** | 134.3 | 0.42 | **0.2** |
| **Dareh Zereshk** | 130 | 0.4 | **0.15** |
| **Nowchun** | 527 | 0.26 | **0.15** |
| **Masjed Daghi** | 204 | 0.3 | **0.15** |
| **Kahang** | 39 | 0.59 | **-** |
| **Haft Cheshmeh** | 155 | 0.23 | **0.25** |

### 6.3.1. MIDUK COPPER MINE

Miduk copper mine has the distance 42 km to shahr-e-babak city in Kerman province, is located in 132 km of north west of Sar-cheshme copper mine and in mountainous condition with average altitude about 2848 m. This mine was used as copper and turquoise mine. The systematic exploration operation has been done by association of Iranian and foreign companies.

Figure 32. Miduk Copper Mine

Source: lenzor.com

Ore in Miduk is fungi-form with 350*400 m dimensions that it's upper part of consists of oxide-zone (malachite and azurite mineral) and supergene-zone (mostly culcosite). Based on exploration done on this project deposit of the mine is estimated to be 170 million tons with average grade 0.83% copper. In last design 144 million tons ore with average grade 0.85% will be mined in 29 years. Miduk is mined with open-pit method and wastes is carried to dump in around valleys. Technical-economic studies done from 1968 to 1994 and primal operation such as road building, power, welfare and services foundations, concentrating factory, dam construction and mine started in 2005. [28]

### 6.3.2. SARCHESHMEH COPPER MINE

Porphyry copper deposit of Sarcheshmeh is one of the largest of its kind in the world. Sarcheshmeh copper deposit is situated at 160 Km Southwest of Kerman, 50 Km South of Rafsanjan and at the average altitude of 2,600 Meters and maximum altitude of 3,000 meters.

Figure 33. Sarcheshmeh Copper Mine

Source: asriran.com

It is located at central Zagros mountain range and is composed of stratified, sedimentary and volcanic rocks and faults pertaining to third geological era. Total Sarcheshmeh ore reserve is about 1.2 billion tons of sulfide ore at the grade of 0.7% Cu. [29]

### 6.3.3. SUNGOUN COPPER MINE

Sungun copper deposit is located in east Azerbijan province in mountainous area and North West of Ahar city. Mine is connected to Tabriz city through a road that is about 125 km. This deposit is in the middle of Qarabagh Mountains that highest altitude of the area from open sea is about 2390 m.

Figure 34. Sungun Copper Mine

Source: NICICO.com

Base on the exploration through 1979-1993 confirmed reservoir of this mine is about 740 Million tons with copper grade 0.661% and molybdenum grade 240 ppm, probable reservoir is about 1,700 million tons.

From 1993 complete technical studies started by Iranian and foreign consultant companies. Result of these studies is open-pit method with 384 million tons ore reserve with grade.0665% for 31 years in 4 phase with total overburden 680 million tons (w/o=1.8), annual production is 7 million tons for first 5 years and 14 million tons for remaining years. Concurrent pre-stripping operation started and from 1999 other part of mine like road building, refinery factory, dam building, pre-stripping advanced faster. [29]

### 6.3.4. DARREH ALOU COPPER MINE

Darreh Alou deposit is located in the southeast of Kerman Province and at a distance of about 150Km from Sarcheshmeh mine having an average grade of about 0.5% Cu in granodiorite intrusion (that has the most amount of mineralization).

Figure 35. Darre Alou Copper Mine

Source: mehrnews.com

Most of analyzed samples show copper concentration of about 0.25% while Mo content is not as considerable as it can be called accessory metal. As a matter of fact, it can be considered as a sub economic porphyry copper deposit that is associated with Oligomiocene diorite/granodiorite to quartz monzonite stocks. [30]

### 6.3.5. CHAH FIROUZEH COPPER MINE

The Chah Firouzeh porphyry copper deposit is located in 35 km north of Shahre Babak (Kerman province). It is associated with granodiiorite intrusive of Miocene age which intruded Eocene volcano sedimentary rocks. This deposit contains Cu sulfide grading > 1% Cu. [29]

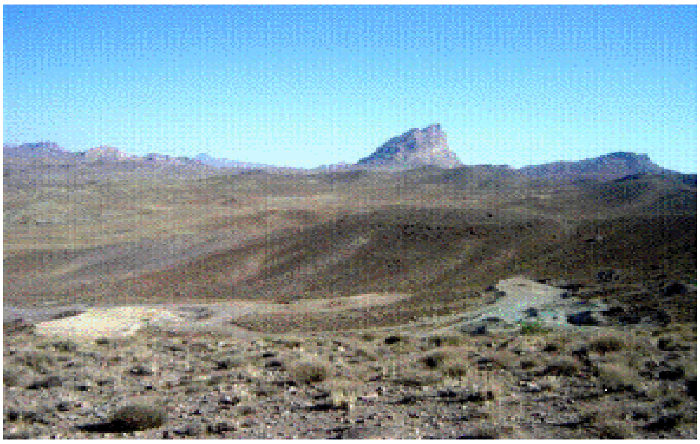


Figure 36. Chah Firouzeh Copper Mine

Source: NICICO.com

### 6.3.6. EJOU COPPER MINE

Ejou is located in 42 km northwest of Shahr-e Babak and 140 km of northwest of Sarcheshmeh copper deposit. [29]

Figure 37. Ejou Copper Mine

Source: fooladnews.com

### 6.3.7. DARREH ZAR MINE

Darreh Zar deposit is located in central Iranian Volcanic belt . It is located 8 km of southeast of Sarcheshmeh porphyry Cu deposit in Southwest of Iran. [29]

Figure 38. Darreh Zar Copper Mine

Source: NICICO.com

## 6.3.8. DARE ZERESHK COPPER MINE

Darreh Zereshk deposit is located on the Yazd - Shiraz main road 60 km south west away from Yazd. Exploration research started with drawing geological map in the scale of 1:2000. The data of the 17 DDH were drilled 30 years ago by a French company, with data from 3 DDH were drilled recently by Kanifaravaran engineering company were considered for research evaluation.

Figure 39. Darreh Zereshk Copper Mine

Source: javanonline.ir

Afterwards accurate evaluation of the ore reserve was done by using classic statistical (cross-sectional, polygon, triangle and Surfer package). Finally the average reserve was evaluated 86 million tons with an average grade of %0.369 Cu classified in B class. Evaluation was extended using statistic in cross sectional method. Results showed that reserve can be 87 million ton with an average grade of %0.341 cu. [31]

## 6.3.9. NOCHOUN COPPER MINE

Nochoun mine is located near Nochoun village, at 4 km southwest of Sarcheshmeh copper mine and is located 10 kilometers northeast of Pariz city. The first systematic exploration studies in this area have been done in 1970 and 1974 by Yugoslavia geologists.

Figure 40. Nochoun Copper Mine

Source: javanonline.ir

In 1990 to 1993, exploration work continued by National Iranian Copper Industries Company. Between 2006-2008, detailed exploratory studies were conducted. [29]

### 6.3.10. MASJED DAGHI

The NICICO has carried out wide-spread exploratory activities at this mine deposit. Presently, it intends to receive exploitation certificate from provincial Department of Environment with the aim of commencing its activities.

Figure 41. Masjid Daghi Copper Mine

Source: Tabriz.isna.ir

Actual mine gild deposit stands at 3,150,000 tons, valued at 180,810 thousand dollar while its probable reserve is equal to 1,440,000 tons, valued at 45,562 thousand dollars. [32]

### 6.3.11. KAHANG

Kahang prospect is located near the village of Kahang in Isfahan province, central Iran. DORSA Pardazeh company (the exploration license holder) discovered Kahang porphyry type alteration system (5km by 2.5km) in 2002 by mapping hydrothermal alterations using Landsat-TM satellite imagery data. Kahang lies in the central part of the main volcanic arc of Iran, which is also known as the Urumieh-Dokhtar Magmatic arc. The Urumieh-Dokhtar arc is one of the main subdivision of Zagros orogenic belt and product of subduction and closure of new Tethys ocean. It hosts all of the large porphyry copper deposits including Sarcheshmeh, Meiduk, Sungon and Dareh Zar in Iran. [33]

### 6.3.12. HAFT CHESHMEH

The Haftcheshmeh porphyry copper deposit in Alborz–Arasbaran Magmatic Belt (AAMB) of northwestern Iran is hosted by I-type granitoids of calcalkaline series of Eocene to Miocene age. The mineralization consists of chalcopyrite, molybdenite, rare amounts of covellite, pyrite, and magnetite that are commonly found in silicified veins of the potassic–sericitic alteration zones in the host quartzdiorite, quartzmonzonite, and granodiorite porphyries. [33]

### 6.3.13. ALI ABAD COPPER MINE

Ali Abad copper deposit is located 35 kilometers southwest of Taft. Its exploration has been done for the first time in 1970.

According to the 5286 meters of drilling conducted above the copper deposit it has been proven that Ali Abad reserves (with a cut off grade of 0.3 percent) against 20.21 million tons of ore with average grade 0.74% copper.

Figure 42. Ali Abad Copper Mine

Source: sedico.ir

Ali Abad probable reserves of copper ore with average grade of 0.72% copper is 7977375 tons ore. [29]

### 6.3.14. SERENU

Serenu system is located in the northwest of Shahre Babak city at a distance of 55 kilometers and in the neighborhood of Serenu town. It is mainly comprised of two igneous complexes:

younger volcanics and dacite andesite rocks forming within primary tuffs and andesites. They are basically formed during Neogene. This deposit is considered as a barren porphyry copper deposit and contains Cu sulfide grading 0.1% Cu. [34]

### 6.3.15. SERIDUN

The Seridun deposit consists of an Eocene volcanic andesite succession with a gently northeast dipping, which was intruded by at least two phases of copper bearing granodiorite porphyries. They are subsequently referred to as “granodiorite stock”, and affiliated “granodiorite dikes” (Late Miocene). Furthermore, a late barren dike of intergranular quartz monzonite also intruded into the volcanic andesite. A succession of volcanic dacite lava (Pliocene) overlies the intrusions mainly at the west part of the Seridun district. This deposit is also considered as a barren and contains Cu sulfide grading 0.3% Cu porphyry copper deposit. [29]