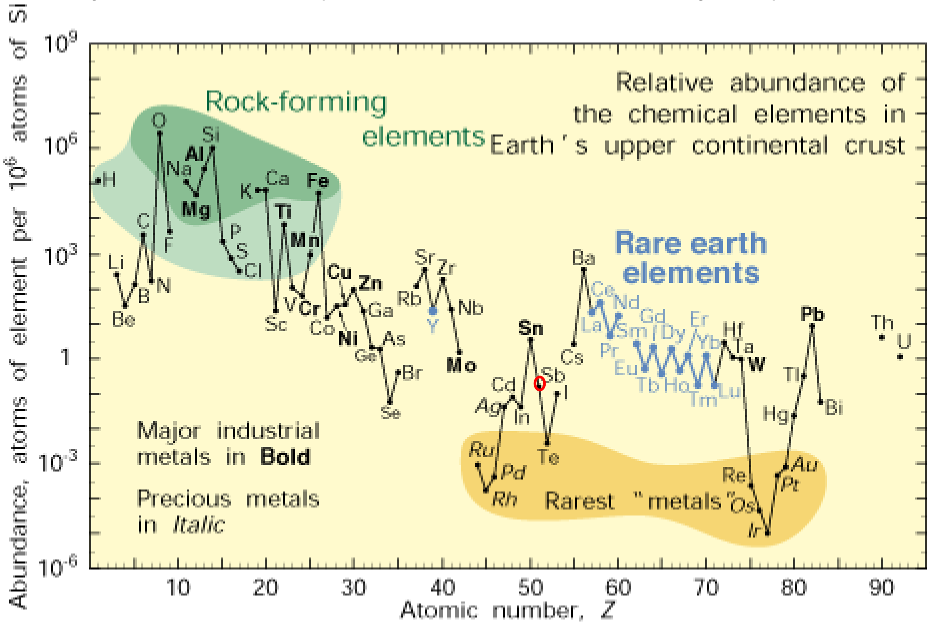
Antimony Uses, Production & Prices

Introduction

The name antimony is derived from the Greek 'never found alone'. The principal use is as an oxide synergist in the flame retardant chemical additive sector. China has dominated world supply for the past 110 years. Antimony (Sb) is a silvery-white, shining, soft and brittle metal. It is a semiconductor and has thermal conductivity lower than most metals. Due to its poor mechanical properties, pure antimony is only used in very small quantities; larger amounts are used for alloys and in antimony compounds. Antimony's abundance in the earth's crust is 0.2 ppm, making the element about as scarce as some of the heavier Rare Earth Elements (REEs) and a little above silver (Ag). [1]

Antimony crustal abundance (chemical element is Sb – central of chart)



(Source: US Geological Survey *2002)*

Antimony is a member of the Group V elements in the Periodic Table, accompanied by tin and tellurium. The atomic number is 51 and atomic weight of 122. The metal is brittle and has a low melting point of 630 ^{o}C and boils at 1380 ^{o}C. [2, 3]

There are over 40 common minerals of antimony but the most important is the sulphide mineral stibnite (Sb_2S_3), which has a Sb content of 72%. The element also occurs as an oxide, valentinite (Sb_2O_3) and as antimonides and sulphoantimonides of metals like lead, copper, zinc, silver and gold. Stibnite has been and to date remains the main source for metallic antimony to be commercially mined. Other common minerals containing Sb that have been found in polymetallic deposits include; [4]

Tetrahedrite $(CuAgFeZn)_{12}(SbAs)_4S_{13}$ a copper associated mineral with a Sb content of 28%.
Boulangerite (Pb5Sb4S11) a lead associated mineral with a Sb content of 25%.
Gudmundite (FeSbS) associated with iron and with a Sb content of 59%.

Geology of Antimony Deposits

China's Hunan Province [6]

Prior to the 1960s most of the world antimony deposits were classified as mesothermal - epithermal fracture filling and metasomatic deposits. The largest deposits in the world were in the Hunan region of China and in the Murchison Belt of South Africa. Both deposits were more akin to carbonate hosted deposits with the action of hot brine transformations.

The most famous deposit is the Xikuangshan deposit in Hunan, reputedly worked since the 16th Century to become a world class producer. The deposit is presently owned by Hunan Non Ferrous Metals Company Limited (HK 2626) listed on the Hong Kong Stock Exchange, but its domestic shares are 65.5% owned by the Hunan Nonferrous Metals Holdings Group Company Limited, a State Owned Enterprise held by the Chinese Government. [5]

Located in the city of Lengshuijiang of Hunan Province, the region is known as the 'antimony world' for China. The area is on an active tectonic fault line known as the EW-trending Nanling belt and has suffered from many earthquakes.

The antimony mineralisation is associated with the upper Devonian age carbonate sequences, limestones and dolomites that occur over a 16km sq area at Xikuangshan. Antimony concentrations in the surrounding rocks enjoy several times the Clarke factor concentrations, most notably the iron formations, limestones & marls as well as shale & slate beds with Sb measurements in the 25ppm to 36ppm range some 50x and 70x above crustal abundance. This indicates the antimony source rocks are within the nearby strata sequence. The ore bearing sequence is the Upper Devonian limestones with intercalated calcareous sandstones, dolomites and shale.

Stibnite formation is intimately associated with silica and deposition is often in high porosity areas associated with limestone in ore bearing formational or karst type void fill patterns.

The Xikuangshan deposit lies along the F75 NS fracture some 9km – 10 km long with deposits forming along and at cross cutting fractures and folds such as F72 and F3. Fractures are more developed than folds and often predate mineralisation. These fractures played an important part in the transport and storage of mineralisation.

The main orebodies at the mine are stratoid or lenticular in shape with feathering like features into the joints and voids of the host limestones. The ore is primary stibnite with a little pyrite. Some antimony oxide was formed. The orebody strike was typically 400m to 600m long with widths of 2m to 7m and grades of around 4% Sb and always associated in a blanket of silica, as silicification is the main indicator for ore prospecting. The deposits were accessed by underground mining and at depths of 100m to 300m below surface. The deposit was thought to contain over 1.9 million tonnes of contained antimony in 2000. This has since been reduced due to ongoing production and the Chinese national reserves as a whole are estimated to be 0.95m tonnes of contained Sb, with Xikuangshan being still the dominant source producing around 40,000 tonnes of contained Sb per annum. [7]

The classification of the Xikuangshan deposit is that of a sedimentary strata source bed that has been exposed to hot brine hydrothermal fluid alteration and remobilisation and enrichment of antimony so as to precipitate in high porosity sections such as favourable anticlinal interformational structural zones transected by great fractures.

South Africa's Murchison Range [8]

The Murchison greenstone belt mountain range is in the North East part of the Transvaal and alluvial gold workings were reported there as far back as 1869. The occurrence of gold, copper, gold and antimony was documented. A mineralized zone in the central portion of the Murchison belt was termed the 'Antimony Line', which refers to an assemblage of carbonate- schist, cherty carbonate and banded iron formation with lenses of quartzites. The Line stretches for a distance of 50km with a width of 50m to 100m and hosts a number of antimony orebodies along it, the most important being the Alpha and Gravelotte mines which began large scale production in 1934.

The Antimony Line refers to the mineralised zone in the central portion of the Murchison Range. It is an assemblage of carbonate-schist, talc-schist, cherty carbonate, chert and banded iron formation with small lenses of quartzite. The Antimony Line stretches 50km with its width ranging from 50m to 100m. It has been exploited in several locations along the Line.

The northern extent of the Line is characterised by berthierite rich ore and banded iron formations, while the southern regions are dominated by stibnite ores. Zoning of stibnite is evident throughout the Antimony Line.

Economically viable stibnite deposits occur as small and discontinuous bodies hosted in hydrothermal veins with quartz. Deformation has played a role in concentrating mineralisation along structural planes and veins. Gold occurs within the Antimony Line as an important by-product.

The deposit was owned for many years by Consolidated Murchison; now 67% owned by Village Main Reef Limited and reports a resource of 9.5 m tonnes at 2.16% Sb with 2.44 gpt gold. The head grade for antimony is 1.5% Sb and for gold is 1.8gpt. The antimony recovery at the mill is reported to be 80% and gold 65%. [9]

Bolivia's Gold-Antimony Belts of the Eastern Cordillera [10]

Bolivia has had a long history of producing antimony from small scale but rich vein type deposits often associated with polymetallics such as gold, lead, zinc and tin.

Three distinctive belts of orogenic gold and antimony deposits containing more than 500 known deposits and occurrences are recognized along the length of the Eastern Cordillera.

Many of the gold districts are in the same general parts of the Eastern Cordillera that have tin mineralization related to Mesozoic and Tertiary intrusions. The orogenic gold deposits, which form ribbon veins, stockworks, saddle reefs, and disseminated ores, are mainly hosted by Middle Ordovician to Early Silurian sedimentary rocks. Many deposits, particularly those of the Caracota-Carma-Candelaria belt, contain as much as 10 to 20% Sb; consequently, many of these were originally mined for antimony. These deposits typically have relatively uniform mineralogy and preserve two principal paragenetic events. Products of the earlier event include gold, pyrite, arsenopyrite, and tungsten bearing minerals in milky quartz. The later, lower temperature event involved deposition of Pb-Zn-Cu– and Sb-bearing sulphides in microgranular, bluish-grey quartz.

The majority of these deposits have been and are being exploited on a small scale from the pre-colonial days to the present. Bolivia recently nationalised the Glencore Vinto antimony facility in 2010 for 'under investment'. [11]

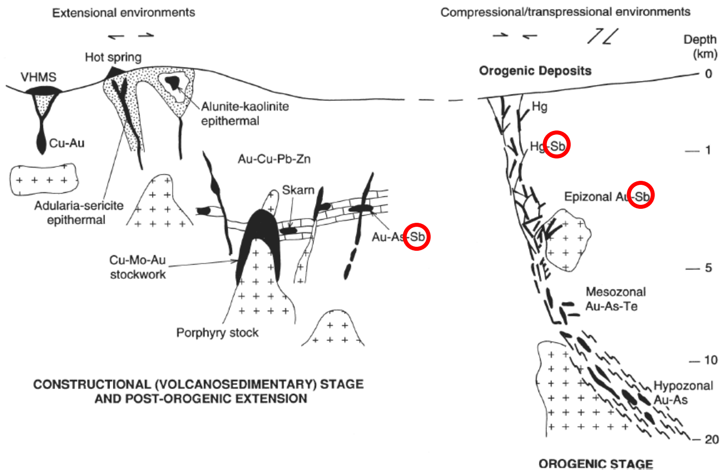
Canada's Eastern Seaboard Antimony deposits [12]

The largest antimony producer in North America was the former Lake George mine in New Brunswick. Mineralisation is associated with a contact between a Devonian granodiorite and Silurian greywackes. Known as the Dunnage Formation and flanked by the Caledonides, the formation traces through New Foundland, site of the current only operating antimony mine in Canada, Beaverbrook, across the eastern flank of Greenland, through Ireland and the southern uplands of Scotland.

The granodiorite intrusion at Lake George and associated fluids, possibly magmatic derived, contained sulphide minerals including Sb, W, Mo and gold. The deposit was discovered in the 1860s and produce sporadically with production reaching a high of 3,000t of Sb content per annum but more normally nearer 1600tpa of Sb contained. The mine closed in the mid 1990s.

Gold deposits with Antimony

Many geologists have observed the association of antimony with gold deposits, such as in parts of Australia and North America. The classification of these deposits has often referred to the occurrence of antimony (Sb) as in the orogenic models below for 'epithermal' style mineralisation. [13]



(Source: Groves et al Ore Geology Review 1997)

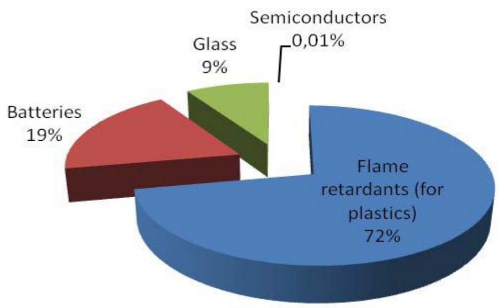
The zonation is attributed to the various boiling points for the minerals, the lighter and nearer surface ones being mercury (Hg) and antimony (Sb) with deeper seated gold and then base metals lower down the system forming at higher temperatures and pressures. Therefore, antimony is often a geochemical indictor for most exploration geologists seeking epithermal gold occurrences.

Other gold deposit models that include antimony are the Carlin sediment hosted hydrothermal deposits of Nevada. Australia has many regions that host gold with antimony occurrences including the Northcote district in Northern Queensland, the Indee district of the Pilbara, Victoria and the Au-W-Sb district in New South Wales. [14]

Other countries and regions with gold – antimony deposits include Serbia, Slovakia, Alaska, Canada and South Africa.

The majority of gold plants recover the precious metal using a leaching agent of cyanide in solution. The occurrence of antimony consumes the oxygen in the solution and hinders the leaching effect of cyanide on the gold ores. Therefore, many antimony bearing gold deposit have in the past had low overall recoveries for the gold by way of using traditional leaching methods. Often these processes were at the expense of antimony which was not economic to recover. [15]

The Uses of Antimony



(Source: Critical Raw Materials – EU Report 2010 Annex V)

In Europe, the principle use of antimony is in flame retardants as antimony trioxide (ATO), which accounts for 72% of its primary antimony consumption. [16] *In China this figure is estimated to be 50% and in the US nearer 60%.* [17] [18] *In this use antimony trioxide is most commonly used as a synergist to improve the performance of other flame retardants such as aluminium hydroxide, magnesium hydroxide and halogenated compounds. This enhanced performance minimises the amount of flame retardant required. Antimony trioxide is used in this way in many products including plastics, textiles, rubber, adhesives and plastic covers for aircrafts and automobiles.*

Around 90% of flame retardant production ends up in electronics and plastics, while the remaining 10% ends up in coated fabrics and furniture upholstery and bedding.

Of the global market share of flame retardants, antimony based oxides represented 115,000 tonnes out of a world total volume of 1.48m tonnes in 2005, representing approximately 7.7% by weight but by value the figure was U$523m for antimony trioxides from total sales value of U$2.865m representing 18.3%. [19]

The world flame retardant market is expected to grow by 6.1% per annum by volume to 2014 and China, already the largest consumer, it is expected to grow by 9.8% to account for 26% of World consumption by tonnage, having over taken the US in 2009. [20]

Antimony trioxide reacts with halogenated compound and creates the chemical compounds, which generate the flame retardant function through the following process. [21]

1)Stop action of thermal de-composite chain reaction under gas phase (Radical trap effect)
2)Sealing action against oxygen under gas phase (Air sealing effect)
3)The formation of carbonaceous char under the solid phase (Air sealing and adiabatic effect)

The second most common use of antimony alloy is as a hardener for lead electrodes in lead acid (LA) batteries. This use is in decline as the antimony content of typical automotive battery alloys has declined by weight to 1.6%, having been 7% in the past, hence the use of antimony in batteries will reduce further as calcium, aluminium and tin alloys are expected to replace it over time. [22] *However, demand from this old segment has risen in recent years due to automotive production in countries such as Brazil, India and China. The World car population is expected to have reached 1 billion in 2010, with the largest being USA with 240m followed by China with 78m cars, having jumped 30% in 2010. World car population is predicted to reach 2.5bn by 2050.* [23] *The traditional market of antimony metal for batteries, although expected to decline with reduced metal content and new battery technologies, still could provide aggregate demand growth due to the shear number of new units being produced for the growing Asian markets.*

Antimony, in the form of sodium antimonite, is also used in glass production as a decolourising agent mainly for optical glass used for cameras, photocopiers, binoculars and spectacles, and in fluorescent light glass tubing. Antimony is also used in some quantities for the following: catalyst in the production of polyethylene and the vulcanization of rubber, pigments, brake linings and ammunition primers.

Substitutes

Combinations of cadmium, calcium, copper, selenium, strontium, sulphur and tin can be used as substitutes for hardening lead; these are already replacing antimony in lead acid batteries. Compounds of chromium, tin, titanium, zinc and zirconium can be used as a substitute for antimony chemicals in paint, pigments, and enamels. [22]

Recycling

No recovery of antimony from flame retardants takes place as it is a dissipative use; antimony is present in low concentrations in high volumes of plastics. However, some uncontrolled and often unintentional reclamation takes place through normal plastic recycling routes as it is retained in the plastic. Traditionally most secondary antimony has been recovered by recycling used lead acid batteries and the material is re-used locally by the same industry [24]

Production, Prices & China

Historical

From 1897 to 1911, the average world production of antimony metal was just over 10,000t with an average metal price of 7.5c (US) per pound (lb), U$165/t. From 1911 to 1914, production increased from 15,000t pa to 22,000 tpa and prices remained at 7.5c per lb. During World War I, production rose sharply to 82,000 tonnes in 1916 as the metal's physical properties for ammunition was deemed important. Metal prices rose to a peak of 32c / lb in 1915 and settled back down to 8c /lb after the War but remained volatile between 5c (ammunition stockpile destocking) and 19c for the rest of the decade. Peacetime demand declined to around 22,000 tpa with America consuming 10,000 tpa with a further 5,600 tpa from recycling ore as a by product from lead ore.

The majority of supplies came from China which sold ore under the Cookson Brand, to Britain which at the time was the world's leading metal producer. Chinese producers adopted the silver standard parity for pricing. All types of antimony based ores where shipped to Britain for metal production and re- exported to The US. China accounted for 53% of production, followed by France at 21%, Mexico 10% and Austria and Hungary at 8% in 1913. [25]

Metal prices jumped once more during the Korean war of 1950 – 53, reaching over $1,000/t for the first time in the history of the metal. China dramatically increased its production in the late 1980's throughout the 90's to command 90% of production once more, as shown in the graph below. [22]

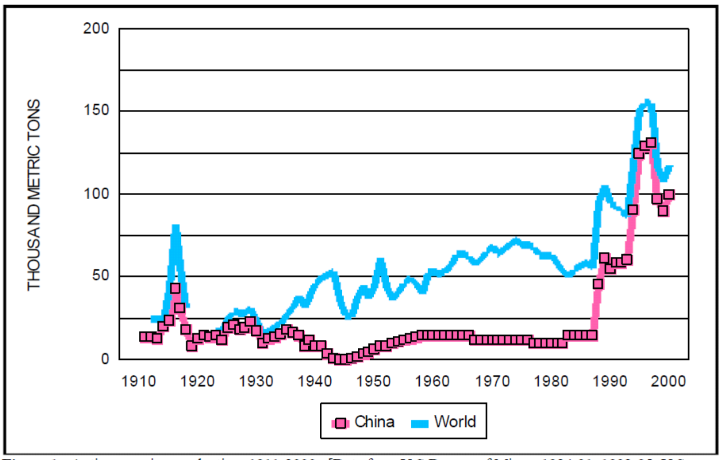


Figure 1: Antimony mine production, 1911-2000. [Data from U.S Bureau of Mines, 1924-31, 1932-95; U.S. Geological Survey, 1910-1923, 1996-2001]

(Source US Geological Survey 2004)

Since 2000, China has accounted for 90% of primary metal produced and World reserves of 53%. [26]

Year	Production ('000's t)			Reserves ('000's t)		
	China	World	(%)	China	World	(%)
2011e	130	145	90%	950	1800	53%
2010	120	135	89%	950	2100	45%
2009	140	155	90%	790	2100	38%
2008	180	197	91%	790	2100	38%
2007	150	170	88%	790	1700	46%
2006	110	134	82%	790	1800	44%
2005	120	137	88%	790	1800	44%
2004	100	113	88%	790	1800	44%
2003	70	82	85%	790	1800	44%
2002	130	148	88%	790	1800	44%
2001	135	151	89%	790	1800	44%

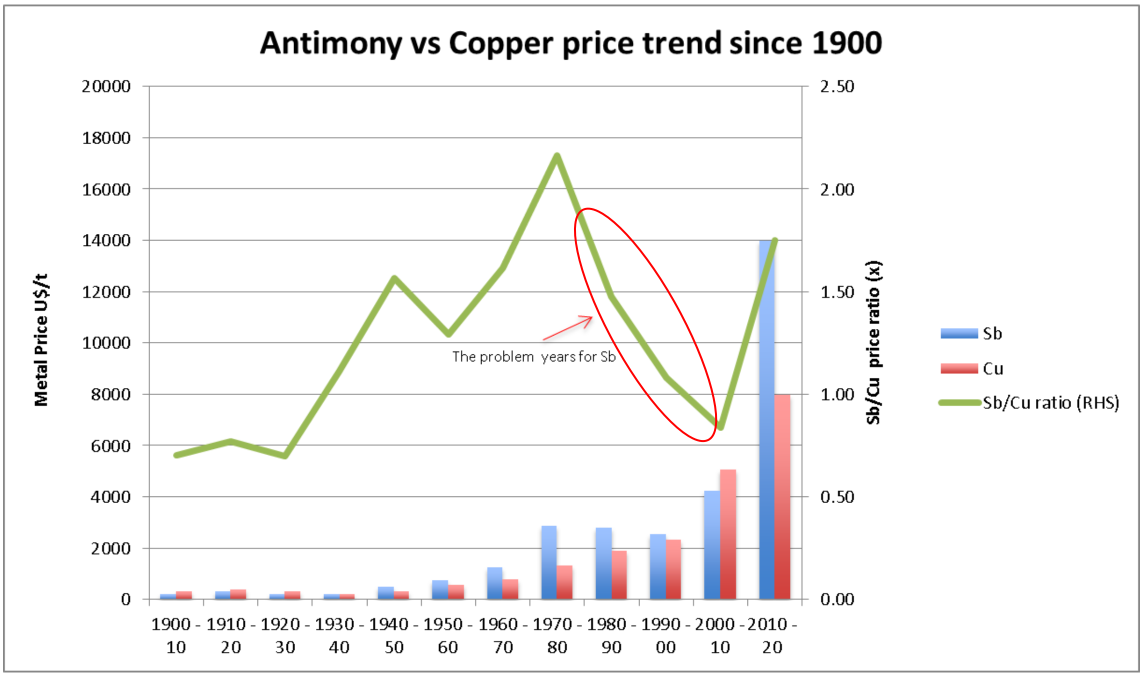
(Source: Complied from data supplied by US Geological Survey 2000 – 20011 Annual Reviews)

China and its position in Antimony

The chart below shows the price of antimony, averaged over the decades, going back to 1900. The price is compared with that of a much wider dispersed metal such as copper. Copper has a much higher crustal abundance than antimony, some 300 times more and with no one country forming a dominant producer. [27]

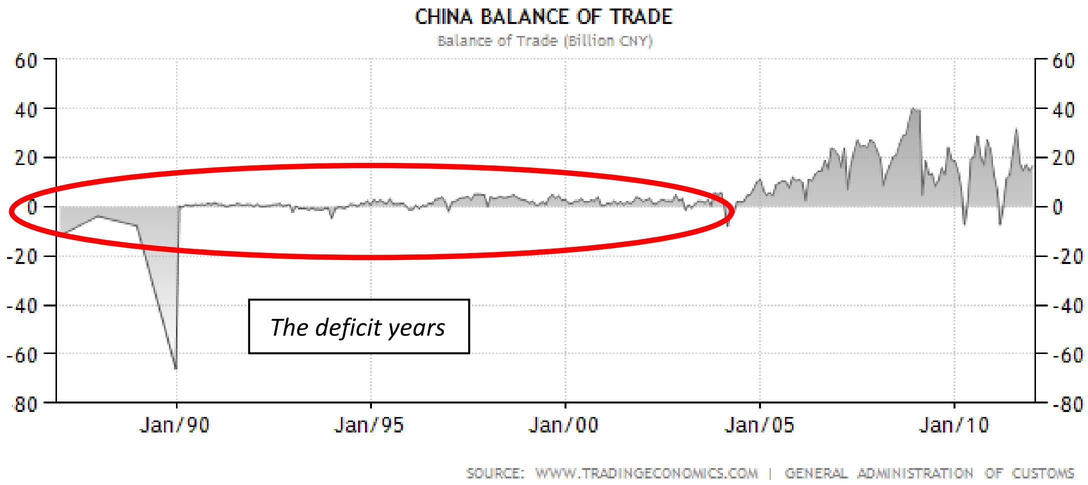
The ratio of the antimony price versus the copper price shows that, as would be expected, the price of antimony rose relative to copper for most of the 20th Century from 1900s through to 1970s. Price spikes were very much linked to Wars and supply disruptions from China, but often the price impact was short lived.

The problem years for antimony were from 1970 – 2000, when the price de-rated relative to copper, despite a growing demand for antimony in new industrial uses. The de-rating at one point brought the metal price to below the copper price in 2000 – 10 decade.



(Source US Geological Survey commodity prices in the US 1990 – 2010 data base)

This relative de-rating of the price of antimony vs copper as a benchmark coincided with the 4 fold increase in output from China. The foreign currency gains for the nation were in the region of U$200m per annum throughout the 1990s and nearer U$500m per annum in the 2000s for antimony exports. Throughout most of the 1980s – 90s China had a trade balance deficit. Its reserves of foreign curreny where only U$2.5bn in 1980's and did not break U$500bn until September 2004. Today they stand at U$3.3 trillion. Therefore, exports of antimony that could earn the country valuable foreign currency were clearly a factor for driving the production and sales of antimony to World markets over these difficult 30 years. For antimony producers elsewhere this lead to the de-rating of the metal price relative to benchmark copper prices. [28]



(Source: TradingEconomics.com 2012)

Current

World mine production of antimony was 135,000 tonnes in 2010 of which 89% came from China. China has been responsible for c.90% of all antimony metal produced globally over the past decade.

World Antimony Production and Reserves – 2010 (tonnes of antimony content)
World Mine Production and Reserves: *Reserves for China, Russia, and Thailand (in "Other countries") were changed based on new information from Government and other sources.* (Source: US Geological Survey 2011)

	Mine production		**Reserves**
	2009	**2010**	
Bolivia	3,000	3,000	310,000
China	140,000	120,000	950,000
Russia	3,500	3,000	350,000
South Africa	2,800	3,000	21,000
Tajikistan	2,000	2,000	50,000
Other countries (Canada/Aus)	3,300	4,000	150,000
World total (rounded)	*155,000*	*135,000*	*1,800,000*

According to these statistics from the US Geological Survey (USGS), worldwide reserves of antimony would deplete in 13 year. [29] *There are obviously more resources around the world to be found and a previous estimate by USGS was for a figure of 4 – 6 million tonnes. This would push the reserve life ratio to 40 years. However, the key demand driver for antimony being flame retardant usage is expected to grow at a rate between 5% pa and 7% pa compound. Taking this into account the reserve life ratio drops to 20 years.*

Outside China, the biggest producer comes from the Consolidated Murchison mine in South Africa which produces antimony concentrate for sale to overseas smelters as a by- product of its gold production.

In 2010, China is believed to have produced 120,000 tonnes of antimony, the vast majority being sold in the form of value added antimony trioxide (ATO). The nation is quoted as having a mining capacity of 90,000 tonnes per annum, again mostly from Hunan district, a smelting capacity of 150,000 tpa. [30]

The nation has imported antimony in concentrate form for reversion into metal and ATO. In 2008 imports of antimony (metal contained) were 19,266 tonnes and rose to 24,661 tonnes for 2009. [31] *This figure is reported to have grown 83% in Jan – Nov 2010 and a further 45% in Jan – Sep 2011, suggesting that China imported approximately 60,000 tonnes of antimony in concentrate in 2011.* [32]

It appears that China imports around 5,000t to 6,000t of Sb contained in concentrates per month. In October 2011, the figure was reported to be 5,462 t a drop of 17% from October 2012. The total import figure stood at 51,664 tonnes at the end of October 2011 up 38% for the same period in 2010. [33]

China has maintained export quotas on antimony for much of the decade, ranging from 70,000 tonnes in 2002 to around the 59,400 tonne for 2012, the majority has always been encouraged to be that of value added exports of antimony trioxide (ATO) leaving only limited exports of metal for the world market. [34]

Estimating China's domestic consumption of antimony and ATO is often clouded by the re-exports of product and by imports of concentrates. However, a straightforward approach would be to consider that China produced 120,000 tonnes of antimony in 2010 and exported 60,000 tonnes, leaving 60,000 tonnes for its internal consumption or stockpile growth. Roughly half the antimony came from imported concentrates and the rest from domestic mines and or stockpiles. China is also therefore a big consumer of antimony as well as being a major supplier.

However, this is too much of a simplification as the true core national demand is obscured by the large exports of consumer goods of the country, as shown in the table below, indicating that China has overtaken the US and Germany in share of world exports. Of the 60,000 tonnes of antimony estimated to be consumed in China itself, how much is used in goods that are re- exported internationally vs. the true domestic consumption of these goods in China itself?

The GDP of China reached U$5.8 Tr in 2010 whereas the US figure was U$14.6 Tr [35] *despite having 4 times the population, and the per capita GDP has a long way still to go to in order to catch up with the US, even though China has experienced high GDP growth rates over the past decade.*

As an exporting nation, China has now overtaken Germany and US as the leading exporter in the world with a market share of 10% (see chart from Economist 2010). [36] *Services play a bigger role in the US economic GDP where as in China the role of manufacturing is larger, estimated to be over 30% and around 10% for the US* [37,] *so China's manufacturing share of GDP is around U$1.7tr (30% of U$14.6 Tr) and for the US it is U$1.5tr (10% of 14.6 Tr). Perhaps in terms of manufacturing the two economies are not far apart, but making different things on the value added scale.*

In 2010 the apparent consumption of antimony in the US was 21,600 tonnes. [38] *A reasonable estimate for the core domestic consumption for China itself may be postulated to be in the region of 25,000 tonnes based on the above.*

(Source: The Economist 2010)

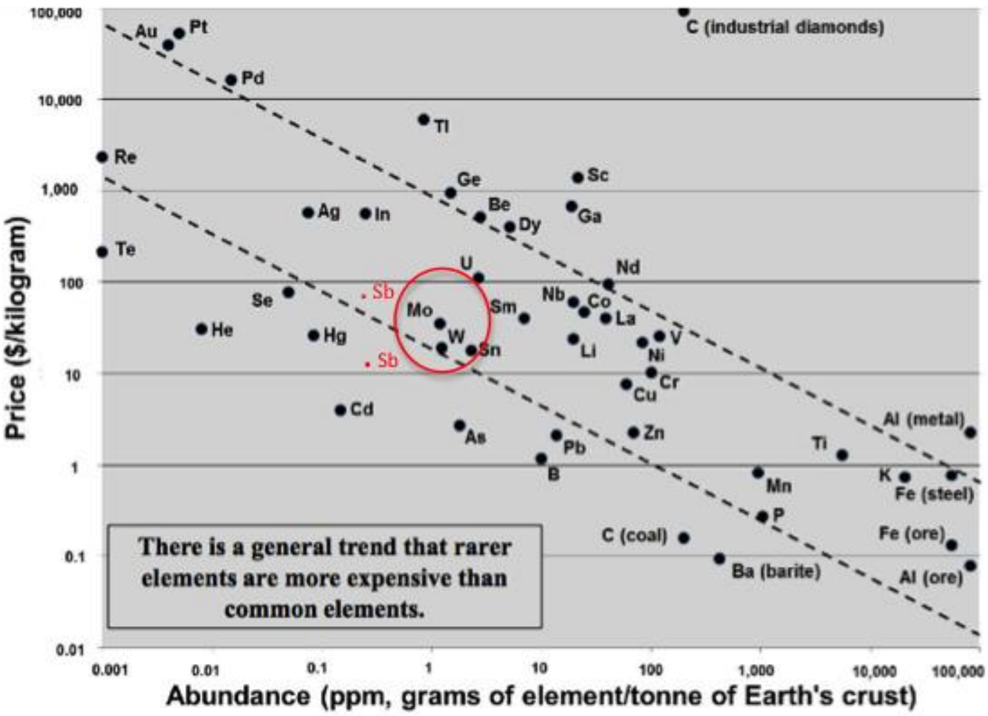
The rest of the antimony consumed in China therefore (35,000 tonnes per annum) would presumably have gone into products that were destined for export. With China's GDP predicted to continue to grow and with an emphasis on stimulating domestic household demand, this internal apparent consumption of antimony in China should rise. China's rising share of world exports over the next few years will also mean more antimony would be utilised in China for its manufacturing sector to re-export in value added consumer products.

China having commanded the World market in supplies of antimony for the past 110 years may well be entering a period in the next decade of becoming an important importer for its own domestic needs.

Antimony Prices

(Source: Metal Prices .com 2012

Metal prices peaked in 2011 at U$17,600 /t and are now trading at U$12,000/t to U$13,000/t having risen from U$4,500 /t in early 2009. [39]



(Source: APS. R Jaffe 2010)

The table above shows the relationship between a mineral's price and its crustal abundance. As expected, the price of more abundant elements such as aluminium and iron, on a logarithmic scale, are commensurately lower than the price being paid in 2010 for more scare minerals.[40] *The plot for antimony (Sb) has been placed in red using the current antimony price and its known crustal abundance to give the lower red point. Note the higher prices for the more abundant minor metals in the list including molybdenum (Mo), tungsten (W) and tin (Sn), equally important elements for the modern industrial world. If antimony was to be priced in context to its more scarce crustal abundance, the price could be higher towards the upper red point. However, many minerals have differing supply and demand dynamics that influence its price and the table above is a point in time snap shot of mineral pricing.*

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