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**REPORT ON THE MARKETING PROSPECTS  
FOR MAGNESIUM**

**MICROFILMED**  
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## CRA Services Limited

Incorporated in Victoria.

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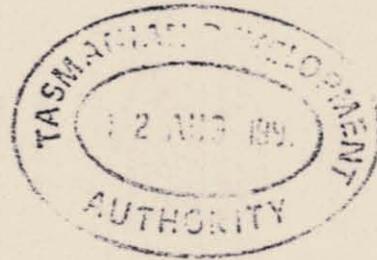
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August 6, 19

**Mr. Brian McBride**  
Manager Major Projects  
Tasmanian Development Authority  
GPO Box 646G  
Hobart 7001 Tasmania



Dear Brian,

### Tasmanian Magnesite

As I mentioned to you by phone following Norm Shepherd's and my return from our travels, the market prospects for caustic calcined MgO, although very promising in the longer term, did not appear forthcoming in the near term.

The major messages Norm Shepherd and I picked up in our discussions with the nine companies we visited in Europe and North America were as follows:

- The overall demand for refractory grade magnesia is depressed due mainly to the economic downturn in the steel industry. Consequently many of the supplier companies are chasing new markets to utilize their spare capacity.
- The new environmental markets for acid neutralisation and the removal of SO<sub>2</sub> from power station (and metal smelter) gas emissions are promising in the longer term (3 to 5 years) but very difficult to develop in the short term.
- The magnesia specialist company needs to engineer a specific solution for MgO or Mg(OH)<sub>2</sub> usage on a customer by customer basis. Accordingly detailed technical, engineering and market experience is required by the producer or supplier of caustic calcined magnesia.
- The foregoing reinforces our thinking that the Tasmanian magnesite project will need to be driven by **market pull** rather than production push. It suggests or confirms to us that strong collaboration partnerships will be necessary with those companies that know the market and are technically competent.
- There is a growing view that natural magnesite will prove to be more economic for the new environmental markets than the high purity, high cost magnesia extracted from brines and seawater. **This is a positive for Tasmanian magnesite.**

- The Chinese natural magnesite materials will continue to represent the major competition to new developments. Because of variability in quality and erratic supply history, the major customers of Chinese material are looking for alternative sources. A premium may be payable for consistent quality and predictable supply.
- For the metal grade magnesite market, the forecasts for major increases in demand were very much dependent on the commitments that the auto industry might make to the metal. There is a chicken and egg issue here. The auto industry won't commit until magnesium is available at a competitive price. At current prices greenfield magnesium smelters/refineries are not economically viable.

Norsk Hydro are seeking to develop new markets using the light weight and castability properties of magnesium. An example is one piece magnesium bicycle frames.

- There was little interest shown by companies to participate with an equity position in the Arthur River project, although the opportunity was discussed.

There were many other points we picked up in our travels and these will be included in a report on the trip which we will be happy to make available to you when completed.

We are now assessing how we should proceed with the project in the future. Certainly we have confirmed our initial view for the need to collaborate with technically and commercially sound partners to ensure the right product/market mix is identified, developed and promoted. It is possible that we will need to select separate parties for each of the European, North American and Far East markets.

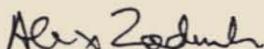
In respect to the Arthur River magnesite resource, we will now need to carefully consider what the next step should be to advance the project further. Discussions internally within CRA and with our Joint Venture partner will be necessary before we can be more definitive.

I trust the foregoing gives you a brief summary of the challenges facing the project.

In conclusion, I should add that the reports on the magnesite project prepared for CRA by the Tasmanian Development Authority were very well received and made a very favourable impression on the six companies which received them. I would like to express our thanks and appreciation for your efforts and support.

Should you have any queries please call me or Norm Shepherd, or if you are visiting Melbourne in the near future, we would look forward to catching up.

Yours faithfully,



**Alex Zadnik**  
General Manager - Business Development  
Resource Commercialisation

c.c. Norm Shepherd

MAGNESIUM METAL

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Summary

The following paper analyses the magnesium industry in the attempt to ascertain whether the key players in the US and Europe are achieving satisfactory profitability at a time when prices are at historically low levels.

An evaluation of a hypothetical Australian based Greenfield plant/smelter is also presented concluding that, at current Mg prices, power costs of Australian 2.2 cents/kWh would be necessary to achieve a CRA required return on investment.

The first half of the paper analyses magnesium's current end-use markets and attempts to get a feel for the degree of price elasticity in each market. This analysis concludes that there is a real possibility that magnesium is currently superior to aluminium on a price/weight competitive basis with the greatest potential for demand growth in the worlds automotive sectors.

The paper concludes with a recommendation that CRA should consider developing our understanding of the following key issues:

- technology trends in the industry;
- current and potential Mg markets (particularly the Asian market).

Supply And Demand For Magnesium Metal

1990 Western World consumption of primary magnesium reached 252,000 tonnes. Primary production exceeded consumption by 8,800 tonnes adding to already bloated inventory levels which reached 43,800 tonnes by year end (i.e. 63 days supply). 65,700 tonnes of secondary magnesium were consumed.

Primary production capacity averaged 295,000 tonnes during 1990 operating at an average utilisation rate of 88%. Production capacity will increase to 328,000 tpa by year-end 1991 with the full commissioning of Norsk Hydro's 40,000 tpa Becancour plant and Magcan's 12,500 tpa Alberta plant.

The average capacity of the thirteen plants/smelters in operation was 25,000 tpa. The lowest cost producer is Norsk Hydro. Capacity owned by Norsk Hydro and Dow represents 55% of the world total and they respectively hold the first and second quartiles of the industry cost curve.

The primary magnesium market is currently 1.7% the size of the primary aluminium market.

Consumption

The following break-down of current primary magnesium consumption on a geographical and end-use basis emphasises the significance of the US aluminium alloying market.

<u>Geographic</u>	<u>%</u>	<u>End-Use</u>	<u>%</u>
North America	52	Aluminium Alloying	53
Latin America	4	Nodular Iron	7
Western Europe	28	Desulphurisation	13
Africa/Middle East	1	Metal Reduction	4
Asia/Oceania	13	Electrochemical	3
Comecon/China	2	Chemical	2
		Die Casting	12
		Gravity Casting	1
		Wrought Products	2
		Other	3
	<u>100%</u>		<u>100%</u>

A major proportion of secondary magnesium is consumed in the desulphurisation sector with the remainder of the scrap typically going to the low quality end of the die casting market. The prime reason for this is the tolerance for low purity metal in these sectors.

Western world demand for primary Mg has grown by 3.1% p.a. since 1983 and 3.6% p.a. since 1986. Most of this growth has been in desulphurisation, aluminium alloying and the US automotive sector. It is important to note that about 10% of Mg utilised in aluminium alloys also finds its way into the automotive sector in aluminium die castings. Automotive Mg die castings compete directly with aluminium die castings, steel and plastic components.

Pricing & Competitiveness

Primary Mg and common alloy list prices have dropped significantly below the long-listed US\$1.63/lb in the US market over the last six months. Common alloys such as AZ91D are currently selling at US\$1.34/lb.

There is intense competition in the North American magnesium supply market with Dow recently slashing its list prices in an attempt to maintain market share and reduce stocks. This is at a time when the US supply market is in oversupply as greenfield Norsk Hydro and Magcan capacity comes on line. Dow's list prices have dropped \$0.30/lb since November 1990 (i.e. 18%) in a market which previously had not witnessed a decline in list prices since 1943. The other producer list prices have followed Dow's lead.

Prices in Japan and Europe have, up to now, apparently maintained their US\$1.70/lb levels with supply and demand in balance. The higher cost Japanese and European producers (excluding Norsk's Porsgrunn plant) require such prices to cover costs of production.

The key issue is will US prices maintain their current historically low levels and drag down Japanese and European prices.

If current US Mg prices are maintained, it is possible that magnesium will pressure for displacement of aluminium, steel and plastics in those markets where magnesium usage has been retarded by its relatively high price. Fewer technical constraints limit magnesium's use nowadays with the advent of new, high purity alloys and development of more efficient casting technologies.

Three key factors will determine the extent of displacement of competing materials by magnesium products on a price basis:

- the price elasticity of demand in Mg's current and potential end-use markets;
- that price level of Mg necessary to trigger substitution considering each competing material's relative physical characteristics;

- the ability of the primary Mg producers to maintain prices at or below the substitution "trigger price" level.

A critical non price factor affecting the rate of market penetration is the ability of parts manufacturers to change their production technology for magnesium, and acceptance/demand by the auto makers, etc.

#### Price Sensitivity of End-Use Markets

Aluminium alloying is Mg's largest end-use market and demand in this sector is largely insensitive to Mg price fluctuations. Aluminium alloying represents 53% of total Mg demand : 50% of this is taken up by aluminium cansheet production, 40% in other aluminium extruded and general sheet and plate products, and a bulk of the remaining demand in aluminium die castings. The value (and content) of Mg in these end-use products is relatively small.

Mg's share of the desulphurisation market had been experiencing strong growth prior to the recent Mg price cuts. Increasing quality pressures on iron and steel producers combined with the recent slide in Mg prices may result in stronger growth. However, it will be the sulphur-related quality issues of iron and steel production which will play the leading role in this market with the price of Mg being a secondary issue.

Potential usage of Mg alloys in the world's transportation sectors represents the industry's greatest opportunity for growth on a price basis. The decision criteria used by auto producers in the selection from competing component materials includes quality and volume surety, ultimate component weight, fabrication costs and the relative price/weight ratios of competing materials.

#### Magnesium Usage In Automobiles And The Mg/Al Equivalent Price/Weight Ratio

In 1990, average Mg content per US automobile reached 4.0 lbs compared to a almost zero content ten years ago. Less than 1.0lb of the Mg content was used in aluminium alloys. The remaining 3.0lbs of Mg was in Mg alloy die castings and typically at the expense of aluminium die castings. The average aluminium content in US passenger cars is 176lbs.

Mg alloy components have been used in cars since 1921. The Volkswagen "Beetle" used a magnesium engine block and transaxle housing with a combined weight of 43lbs per car. However, auto producers argue that Mg prices and corrosion problems (due to an inability of the Mg industry to cast high purity alloys) have restricted the number of Mg applications.

Although Mg content in US autos is only 3% of aluminium content the number of auto companies (and car models) switching to Mg components is increasing. There have been six separate announcements of decisions (detected by R&PD) by US auto producers to switch to magnesium components in specific applications over the last two years. There have no doubt been more than that.

Comalco are currently investigating the potential of magnesium lithium alloys in autos.

Increased Mg activity might suggest that Mg prices have slid below the "equivalent" material price/weight ratios of competing materials and as a result substantially increasing the attractiveness of Mg components to auto makers.

The following analysis attempts to approximate the Mg/Al price/weight ratio necessary for substitution to occur:

- Mg is two-thirds the density of aluminium. The lower weight of Mg components automatically dictates a 1.5Mg : 1.0Al equivalent primary metal price ratio;
- GM claims that they are prepared to pay a 20% premium on Mg components over Al components (over and above the price/weight ratio). This premium reflects the pressures (both legislative and market) on auto makers to reduce vehicle weights and the opportunity Mg offers them to do so;
- an estimated 15% savings in the unit manufacturing costs of Mg components over Al components due to longer tool life (Mg does not attack tool steel whereas aluminium does), longer die life (thermal fatigue is substantially reduced), reduced energy utilised in machining, etc.

The above analysis demonstrates that a sustained primary metal price ratio of 1.85Mg : 1.0Al may represent that ratio where the cost of magnesium components would be

considered equivalent to the cost of competing aluminium components, by auto producers. A range of equivalent ratios between 1.7 times to 2.2 times are quoted by industry sources.

During the 1981-1990 period, the annual average Mg/Al price ratio has exceeded 2.0Mg : 1.0Al in seven of the ten years (1981 thru 1987). The ratio in 1988 and 1989 was below 1.85 times with declining aluminium prices last year raising the ratio to fractionally below 2.0 times.

The current price ratio is 1.64Mg : 1.0Al. The 1.85 times equivalent price ratio suggests that when Al is US \$0.81/lb the equivalent competitive Mg price is US\$1.50/lb.

The above analysis suggests that auto makers could significantly shift their preference to magnesium components if current or sub US\$1.50/lb Mg prices are sustainable.

The critical issue is can sub US\$1.50/lb prices for primary Mg be sustained. The fundamental determinate in answering this question is the level of profitability of current and future producers at or below this price.

#### A Greenfield Plant in Australia

An evaluation of the returns on investment that could be expected from the construction of a 50,000 tpa magnesium metal plant in Australia indicates that at current prices of US\$1.34/lb such a plant could sustain a satisfactory return if power could be sourced at or below 2.2 Australian cents/kWh. At US \$1.50/lb Mg, the equivalent power price would need to be at or below 4.6 cents/kWh.

The evaluation is based on the construction of a plant utilising Norsk Hydro's HCl acid digestion/electrolytic technology (identical to Norsk's "state of art" Becancour plant). In the financial evaluation it is assumed that magnesite ore requirements (i.e. 190,000 tpa) are sourced from Kunwarara at current commercial prices (i.e. A\$90/tonne). It is anticipated that Tasmanian sourced magnesite would be less expensive than the already operational Kunwarara mine. The plant would require approximately 130MW of power

and the plant's entire output is assumed to go into the Asian market. In practice, there would be a small domestic Australian market (i.e. 5,000 tpa).

Norsk's Becancour plant currently pays 1.0 US cents/kWh for power (5 year contract with the price rising to 2.4 1991 US cents/kWh in 1996). The Becancour plant requires an Mg price of US \$1.32/lb to achieve a satisfactory return on investment (on CRA criteria) and US\$1.45/lb when the cost of power increases in 1996. In other words the plant can achieve satisfactory profits at a sales price below the US \$1.50, Mg substitution "trigger" price.

Norsk's brine technology based Norwegian plant (50,000 tpa) has higher operating costs than its Becancour counter-part. However, this process produces large quantities of chlorine as a by-product which it sells to a nearby Norsk owned company at commercial prices. When these by-product credits are taken into consideration, the net unit cash costs of the Norwegian plant are approximately US\$0.13/lb lower than the Becancour plant. The Becancour plant also produces significant quantities of chlorine. However, the chlorine is used for "in house" production of HCl which is fundamental to the plant's magnesium chloride production process.

Norsk's two plants represent the bottom 27% of the cost curve (1st quartile) and would generate satisfactory profits at current prices.

It is estimated that Dow's current unit cash costs (90,000 tpa) are approximately the same as those costs expected at Norsk's Becancour plant once the cost of power increases in 1996 (i.e. requires a 1991 US\$1.45/lb Mg price). Dow would be unprofitable at current prices and it was Dow who initiated the recent price cuts. It is possible that this price strategy is not only driven by the fact that the US market is in oversupply but also a signal to Norsk and Magcan not to increase capacity any further.

In summary, 55% of the current primary Mg supply market would make satisfactory returns on investment at a long term Mg metal price below the US\$1.50/lb substitution "trigger" price. The remaining 45% of capacity (i.e. AMAX, Magcan etc.) is high cost and requires prices at levels around US\$1.65/lb. This equates to a 2.0Mg:1.0Al price ratio.

Considering Norsk's potential and aspirations to expand the Becanour plant (up to 60,000 tpa within six months of a decision to proceed and possibly up to 200,000 tpa in the medium to long term) it is quite possible that Norsk and Dow will maintain sub US\$1.50/lb Mg prices and achieve two objectives. Firstly, they would squeeze out the high cost producers (i.e. Amax, Magcan etc.). Secondly, they would maintain a price regime which would probably result in strong demand growth for Mg products in the auto sector at the expense of aluminium and possibly plastics.

An important question is why didn't Dow adopt such a pricing strategy previously (i.e. below the proposed substitution trigger price of US\$1.50/lb) if their total costs would have enabled them to do so profitably. It is possible that they viewed their Mg business as a "low effort cash cow". They may have concluded that the lag between the time of reducing alloy prices (and as a result generate new demand for Mg) and the time necessary for downstream industries to introduce new and greater capacity, was too long. Another explanation might be that Dow's strategy was based on the perception that Mg's corrosion limitations would overwhelm any effect that price might have. There is still debate today on the corrosion issues. There are still perceptions in the market that Mg components will fail in some applications due to its corrosive qualities.

Whatever the reason for Dow's previous pricing strategies, it is clear that the industry is no longer dominated by Dow and the emergence of Norsk Hydro has certainly changed the power structure of the industry. Norsk would have to be considered the market leader as their production capacity is equivalent to Dow's but their costs are much lower.

New entrants into the primary Mg industry will not be able to do so using Norsk or Dow technology. The current "duopoly" power structure (i.e. Norsk and Dow) is protected to a certain extent by the fact that neither Norsk or Dow licence their technology out. A new entrant would have to either access existing high cost technology (e.g. Magcan) or develop new technology (e.g. CSIRO).

A cost competitive Australian plant selling into Asia (Japan in particular) could possibly generate similar enthusiasm to that being witnessed in the US auto sector. Japanese cars currently contain very little Mg. However, the potential for increased demand is high if metal becomes available at prices below historical transaction prices.

Conclusions

The potential threat that magnesium currently poses for aluminium is real and potentially significant. Were Mg to capture an average of 50lbs per US car, bus and truck, this would equate to a 250,000 tpa. This equates to one aluminium smelter's output. Were the same thing to occur in Japanese vehicles (i.e. 50lbs of Mg) the equivalent tonnage of displaced aluminium or other materials would be 295,000 tpa.

Further work is needed so that CRA can deepen our understanding of technology trends. An advancement of existing Mg technology would change the equation further.

A greater understanding of current and potential Mg markets (particularly Asia) is required. Will Dow expand along with Norsk or will their higher power costs (approximately 4.0 US cents/kWh) hold them back?

Some  
Key Marketing Research  
Issues

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1. The Asian Market. Why is Mg Consumption less prevalent in Asian markets relative to the US? The Japanese auto sector is the world leader in the light-weighting of automobiles. Why has Mg not played a role in this process?

Factors which may be relevant are:

- The lack of Mg production capacity close to the Asian markets resulting in non-competitive Mg transaction prices into those markets
- Current and future Mg fabricating capacity and technologies in Asia
- The development of close links between aluminium fabricators and die castors and auto producers
- Auto-manufacturer attitudes.

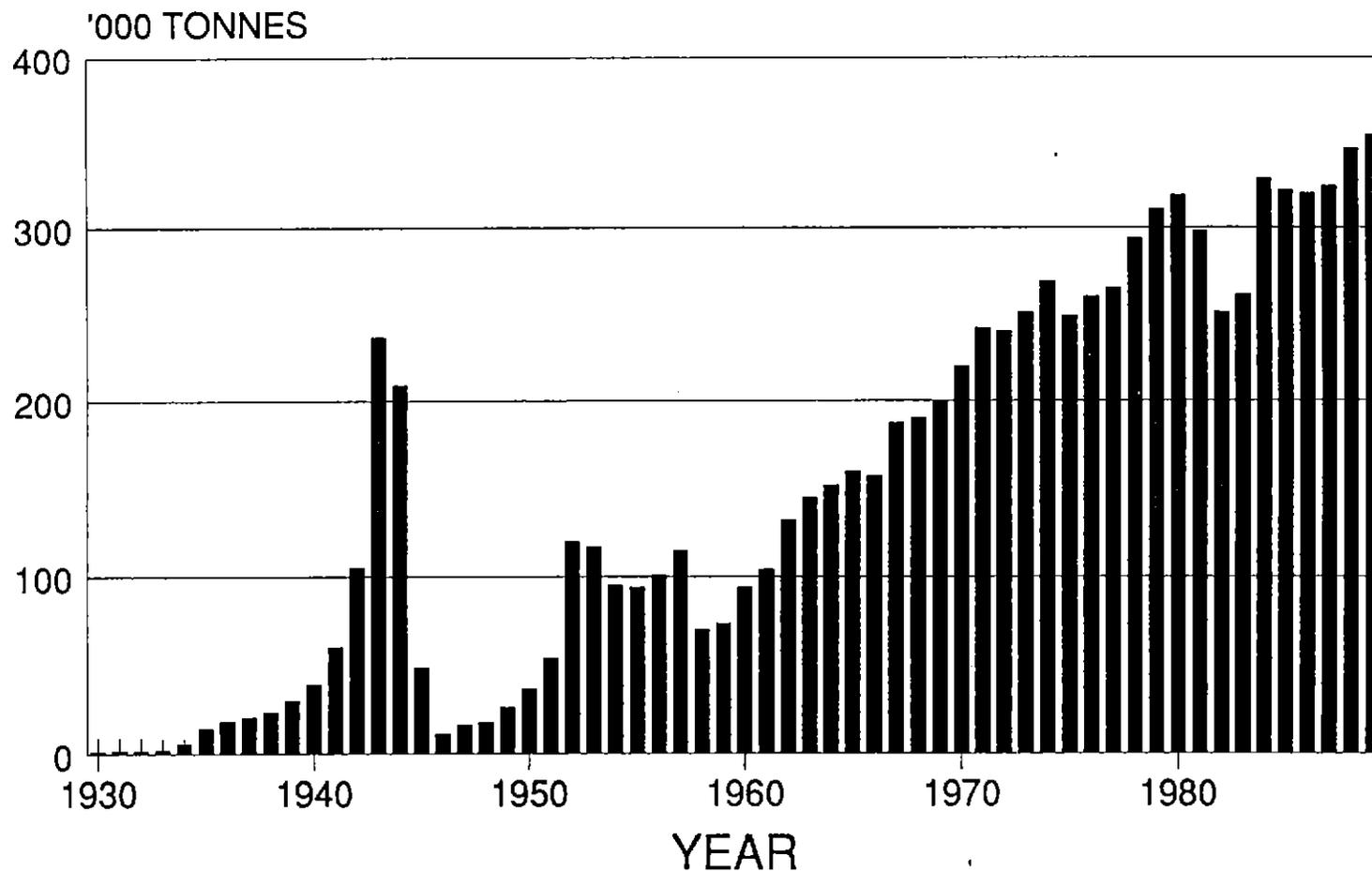
2. Mg: AL Price Ratios. A simplistic ratio of 1.5 Mg:1.0 AL can be calculated on a metal density basis. What is the proportion of auto components utilised in autos in the Asian automotive sectors that are:

- Utilised purely on a weight basis with relative indifference to material strength, heat resistance etc.
- Determined by strength characteristics.
- Determined by heat resistant characteristics
- Determined by non corrosion qualities.
- Determined by other technical factors.

Considering the balance of material characteristics required in components used in Asian autos, what should the true equivalent Mg:AL price ratio be incorporating the comparative technical issues? (Including consideration of down stream conversion costs).

3. The Desulphurisation Sector. The Asian Iron and Steel Industries are some of the most advanced in the world. What are the future prospects of Mg usage in these sectors? Are there competing materials which could threaten Mg usage?
  
4. What Are The Key Determinants In Forecasting Future Mg Demand In Asia? What influence would an Australian based Mg plant have (with competitive power costs) on future Mg demand in Asia. What other issues are critical to Mg demand growth? What will total primary Mg demand be in Asia by the Year 2000?

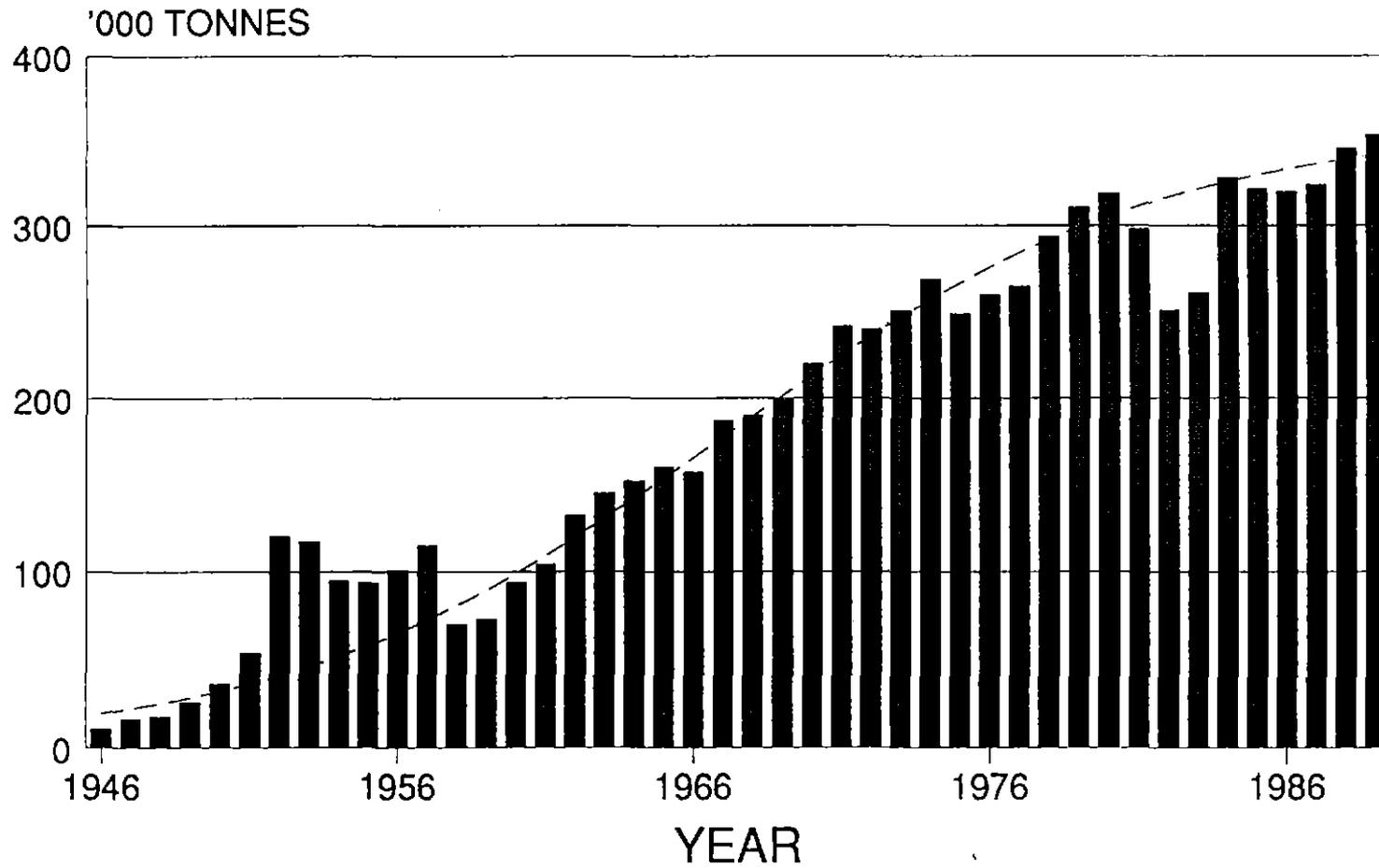
# MAGNESIUM WORLD PRODUCTION



Source : U.S.Bureau of Mines

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# MAGNESIUM WORLD PRODUCTION POSTWAR

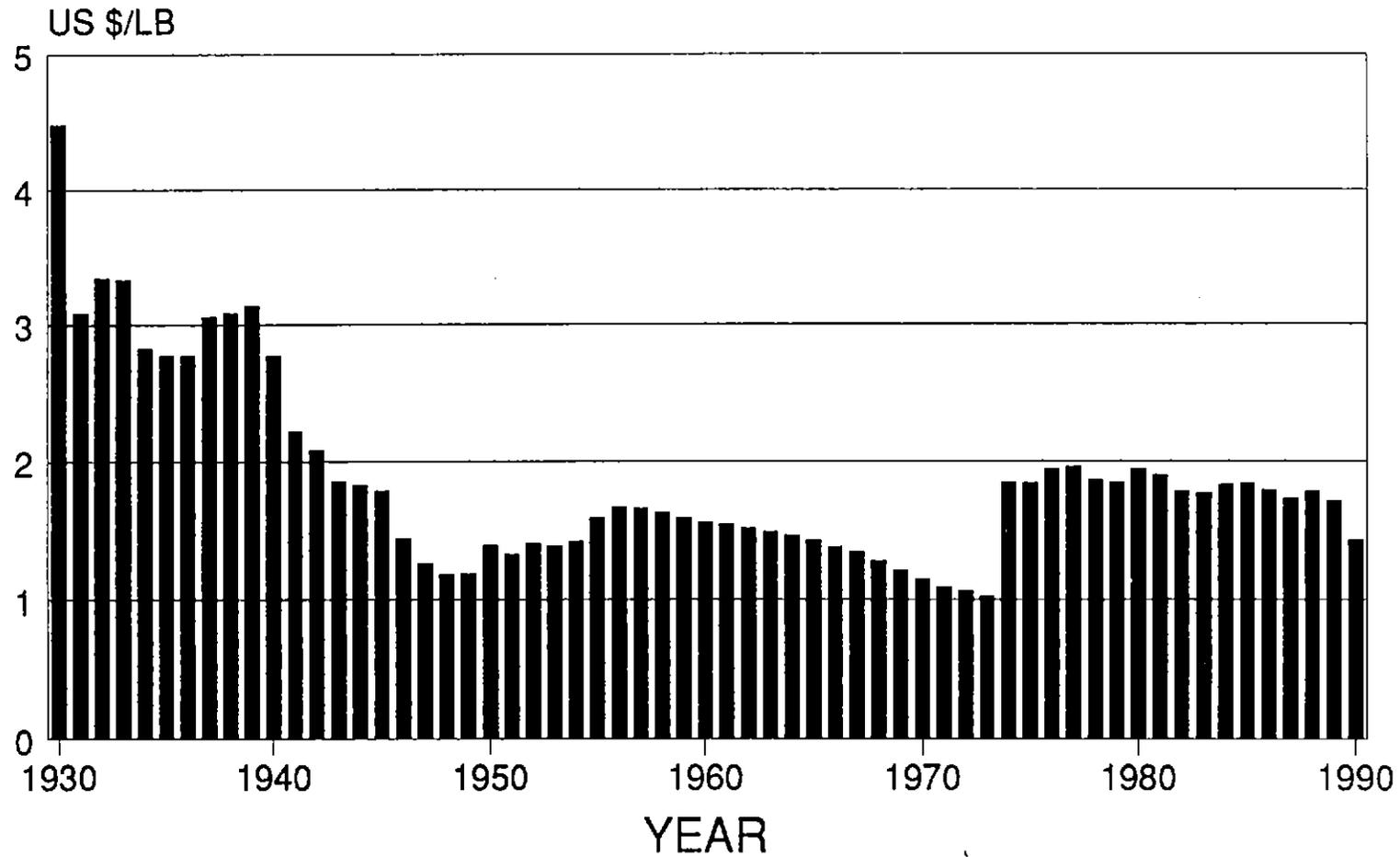


Source : U.S. Bureau of Mines

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# MAGNESIUM

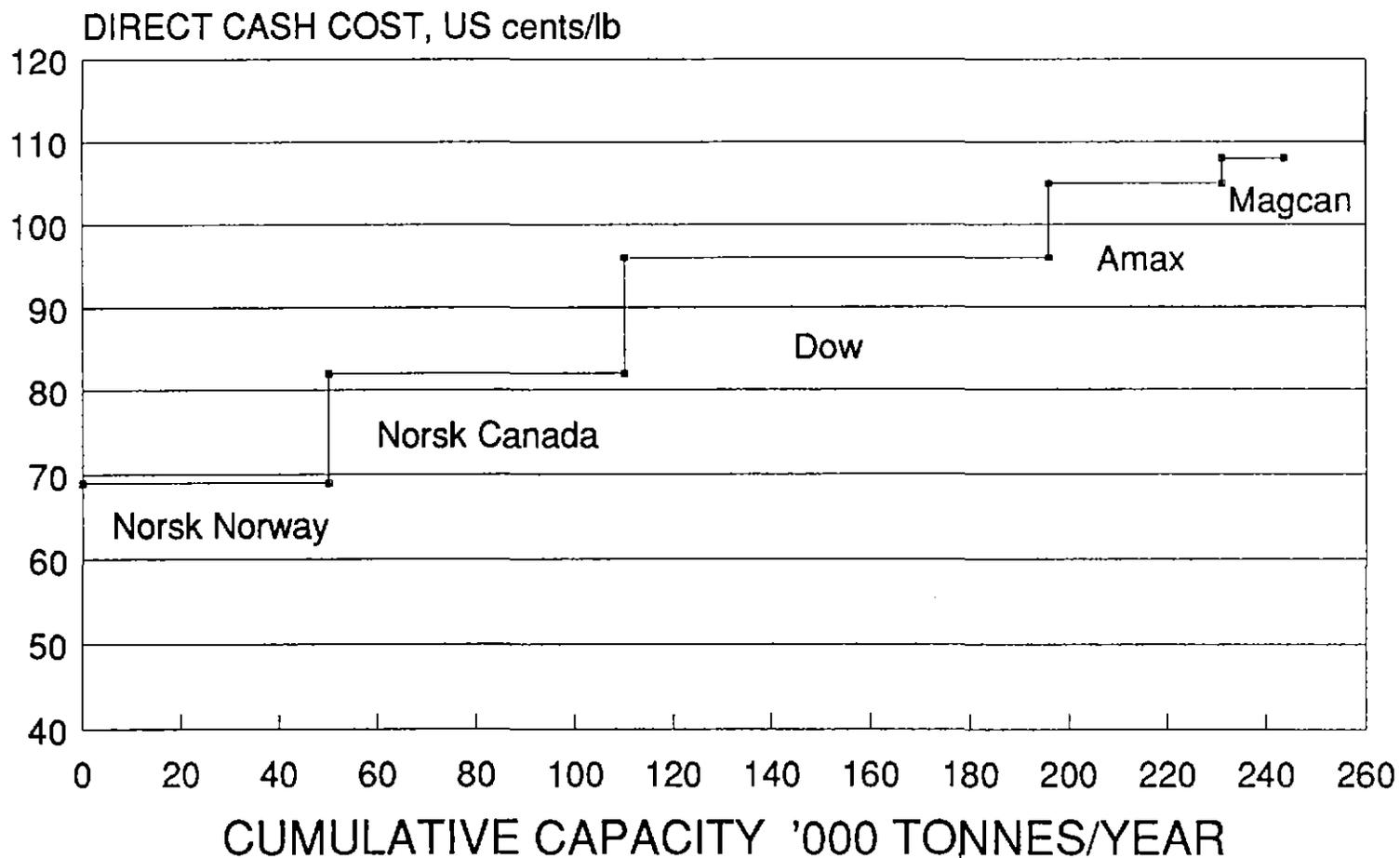
## U.S. YEAREND PRICE REAL 1990



Source : U.S. Bureau of Mines

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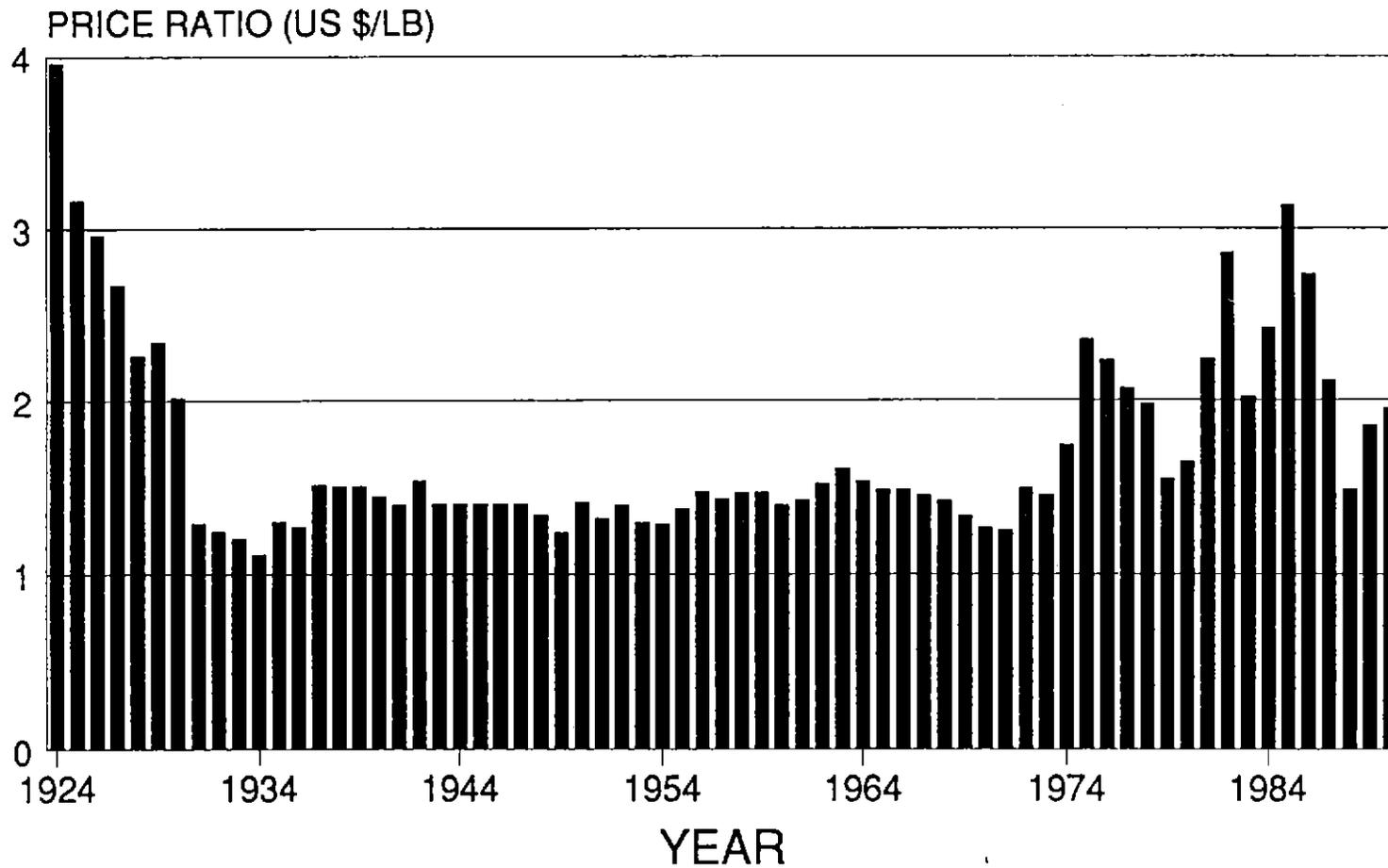
# MAGNESIUM PRODUCTION CASH COST CURVE 1989



Source: Charles River Associates

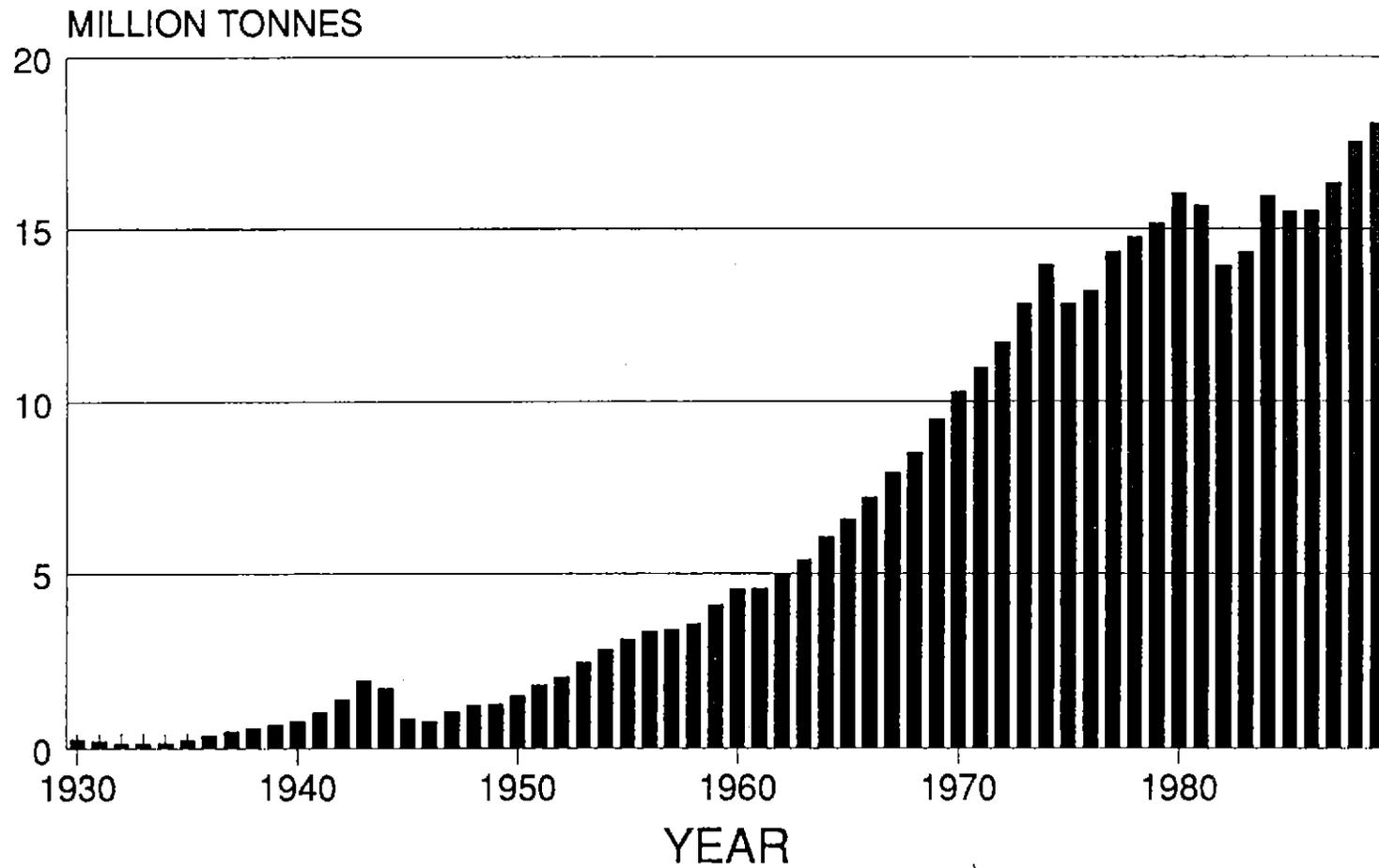
# MAGNESIUM

## MAGNESIUM/ALUMINIUM PRICE RATIO



Source: USBM, Metallgesellschaft

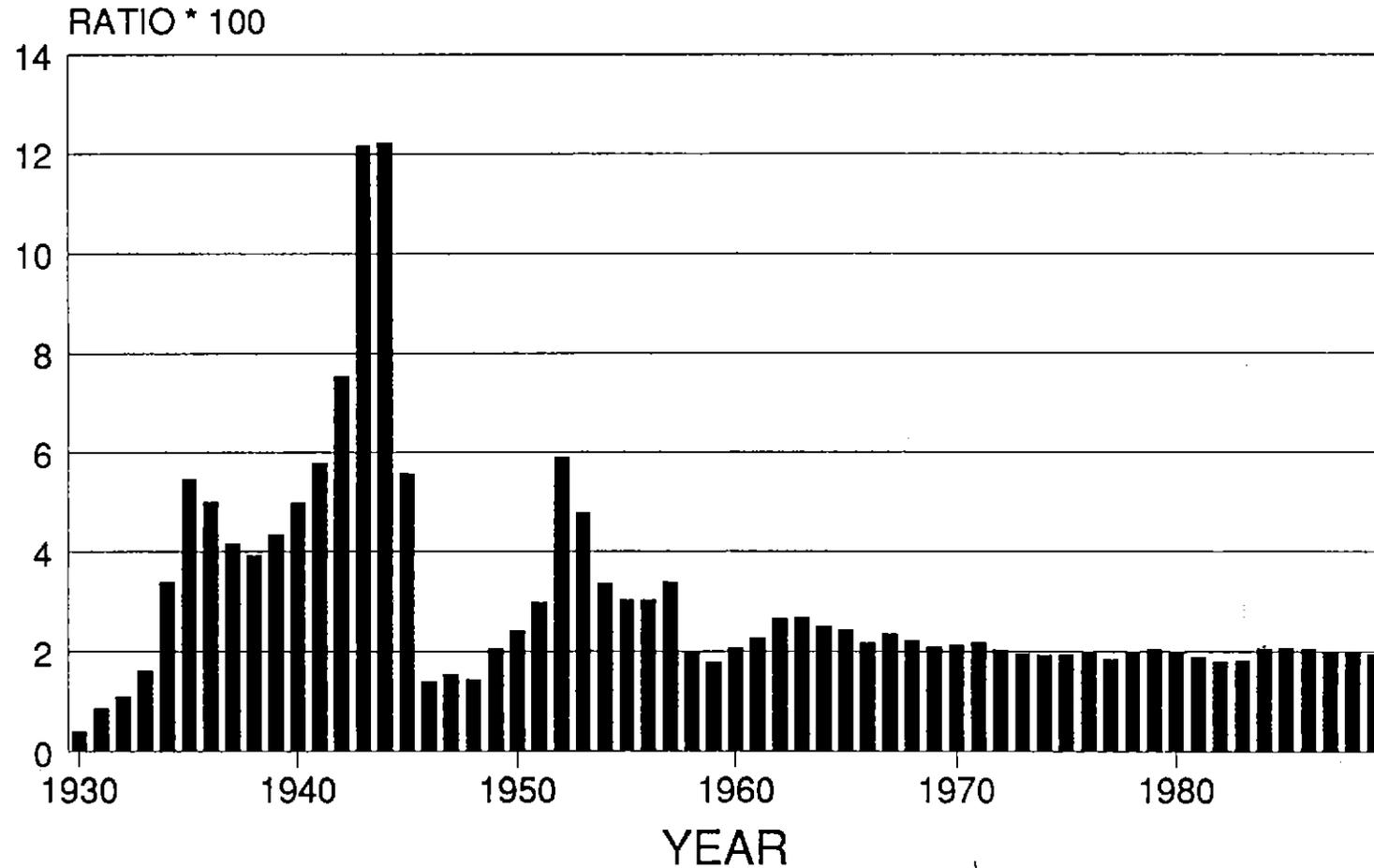
# ALUMINIUM WORLD PRODUCTION



Source : U.S. Bureau of Mines

# MAGNESIUM

## MAGNESIUM/ALUMINIUM PRODUCTION RATIO



Source : Metallgesellschaft