CHANGES IN THE NORTH AMERICAN FERROALLOYS INDUSTRY STRUCTURE AND TRENDS IN THE INDUSTRY DURING THE PAST 20 YEARS

J.R. Didaleusky, J.D. Jorgenson, L.A. Corathers, M.D. Fenton, P.H. Kuck, J.F. Papp, D.E. Polyak, K.B. Shedd

U.S. Geological Survey, Minerals Information Team, 989 National Center, Reston, VA, 20192, USA; jjorgenson@usgs.gov

ABSTRACT

This analysis of changes in the North American (Canada, Mexico, and the United States) ferroalloys industry between 1987 and 2007 includes the locations and types of ferroalloy plants in North America and the changes in production, imports, exports, pricing, and the structure of ownership since 1987, which was just prior to the implementation of the North American Free Trade Agreement. Significant events affect the supply of and demand for North American ferroalloys -- changes in end uses, global industry structure, political stability, and technology. Mergers and acquisitions in the ferroalloys industries of North America and their impact on trade are other significant issues in international trade as are antidumping and countervailing duty orders, and trade agreements and policies related to ferroalloys occurring during this period and affecting the North American region.

Raw materials and energy supply to the ferroalloy industry, the logistics involved in the trade of North American ferroalloys, and the use of ferroalloys within major downstream industries are also important factors. Emphasis is placed on the bulk ferroalloys—ferrochromium, ferromanganese, ferrosilicon, and silicomanganese. Other ferroalloys investigated include those of boron, molybdenum, nickel, niobium, titanium, tungsten, and vanadium.

1 INTRODUCTION

Ferroalloys are a group of materials composed of iron and one or more additional elements which are usually used as addition agents primarily in the manufacture of steel. Ferroalloys are incorporated into the molten stage of the steelmaking process for the purpose of producing specific properties in the steel [1]. The main focus of this paper is to review the structure and trends in bulk ferroalloys—ferrochromium (FeCr), ferromanganese (FeMn), ferrosilicon (FeSi), and silicomanganese (SiMn)—in North America. In addition, ferroboron (FeB), ferromolybdenum (FeMo), ferronickel (FeNi), ferroniobium (FeNb), ferrotitanium (FeTi), ferrotungsten (FeW), and ferrovanadium (FeV) are included in some of the analysis.

In North America—Canada, Mexico, and the United States—transformations in the ferroalloy industry can be traced by analyzing a variety of metrics, including production, trade, and industry structure. Data relating to the above mentioned criteria from 1987 through 2007 are presented. Additionally, criteria are evaluated to assess the effect, if any, of the North American Free Trade Agreement (NAFTA) and its predecessor, the Canada – United States Free Trade Agreement of 1987, on the ferroalloy industry in North America. In theory, the implementation of NAFTA would be expected to increase trade among the three countries. Additionally, it provides a convenient point for comparison of industry activity, since it also roughly coincides with the pre- and post-Soviet Union era.

2 FERROALLOY COMPANY AND PLANT STRUCTURE

To assess the structure of ferroalloy companies and plants in North America from 1987 to 2007, available data were compiled from the U.S. Bureau of Mines and U.S. Geological Survey publications, journals such as Metal Bulletin, and selected internet sources. The results are illustrated in bar charts shown in figures 1 and 2.

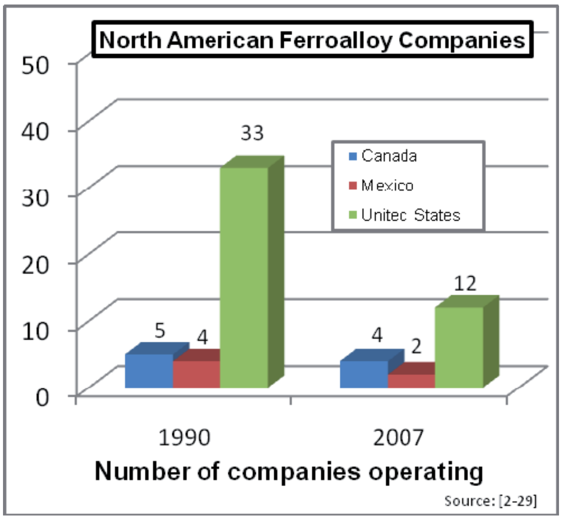


Figure 1: North American ferroalloy companies.

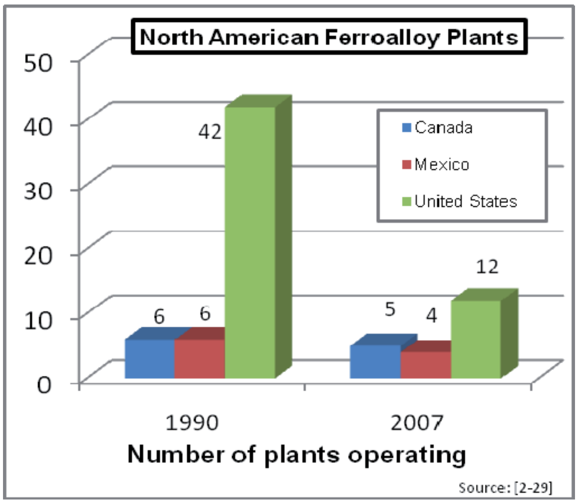


Figure 2: North American ferroalloy plants.

In Canada, the number of ferroalloy companies and plants remained fairly constant, although changes occurred in ownership, and some existing plants closed and new plants opened. Prior to 1990, there were five companies and six plants. As of 2007, four companies and five plants listed in table 1A were operating. The number of ferroalloy companies and plants in Mexico has decreased. Prior to 1990, four companies were open with six plants. As of 2007, there were two ferroalloy companies operating four plants (table 1B). In the United States the number of ferroalloy companies and plants has decreased markedly. Prior to 1990, 33 ferroalloy companies operated 42 plants in the United States. In 2007, 12 ferroalloy companies operated 12 plants in the United States (table 1C).

The decline in the number of ferroalloy producers in North America is the result of numerous factors, including power supply costs, low-priced imports, production shift to ore-producing countries, and higher costs related to environmental and labor considerations. For example, in 1991, Elkem SA produced the greatest volume of bulk ferroalloys in the United States [30-1991, pp. 1375]. However, by 2005, it had sold or closed all four of its ferroalloy plants in the United States [31-2006, pp. 67.8]. In 1988, local power supply problems led Elkem to shut down production at its Pittsburgh, PA, plant [30-1988, pp. 845]. A year earlier, Applied Industrial Minerals Corp. closed its FeSi plant in Kimball, TN, owing to low-priced imports [30-1987, pp. 760]. The declining number of ferroalloy producers in North America, especially in the United States, was a trend that was already observed before 1987. Ferroalloy production increasingly shifted to ore-producing countries and those countries with low energy costs. For example, Brazil, Norway, and Venezuela have relatively low energy costs, while countries such as South Africa and India have high-grade ore sources. In addition, many of these countries increased ferroalloy production as domestic demand rose. This shift of ferroalloy production to ore-producing countries affected many countries, except where quotas and tariffs were in place to aid the domestic producers [30-1987, pp. 360; 1989, pp. 405; 1990, pp. 432, 448-9; 1994, pp. 180].

In the United States, the decline in the ferroalloys industry began in the 1970s. FeCr and FeMn were the principal ferroalloys affected. This decline was the result of low-priced imports of ferroalloys from countries that produced the ores needed for ferroalloy production. The higher labor, energy, and environmental costs in the United States also put the U.S. ferroalloy producers at a disadvantage in the world market.

Investigations conducted by the U.S. Department of Commerce in 1981 concluded that the reliance on foreign producers of FeCr and FeMn posed a threat to national security should there be a national emergency. To help minimize this threat, the Ferroalloy Upgrade Program was enacted in 1982. From 1984 through 1992, Macalloy Inc. and Elkem Metal Co. (now Eramet Marietta Inc.) were awarded contracts to supply the U.S. National Defense Stockpile with FeCr and FeMn, respectively. The aim of the program was not just to increase the national stockpile of FeCr and FeMn; it also was considered important to maintain the ferroalloy production capabilities of the United States by subsidizing the domestic industry [32]. Thus, FeCr and FeMn production in the United States might have declined earlier without the Ferroalloy Upgrade Program.

Table 1: Ferroalloy producers in North America, as of 2007 [2-29].

A. Canada

Company	Company ownership	Plant location	Alloys
Becancour Silicon Inc.	Timminco Ltd. (Canada)	St. Laurent, Quebec	FeSi
Cambior Inc.	IAMGOLD Corp. (Canada)	St. Honore de Chicoutimi, Quebec	FeNb
Elkem Metal Canada Inc.	Elkem A/S (Norway)	Beauharnois, Quebec Chicoutimi, Quebec	FeMn, FeSi
Masterloy Products Co.	Oxbow Carbon & Minerals LLC (USA)	Ottawa, Ontario	FeMo, FeV

B. Mexico

Company	Company ownership	Plant location	Alloys
Cia Minera Autlan S.A. de C.V.	Grupo Ferrominero S.A. de C.V. (Mexico)	Gomez Palacio, Durango	FeMn, SiMn
		Tamos Plant, Veracruz	FeMn, SiMn
		Tezitulan Plant, Puebla	FeMn, SiMn
Nitrocor S.A. de C.V.	H. Popat Holdings (Mexico)	Tampico, Tamaulipas	FeCr, FeMn

C. United States

Company	Company ownership	Plant location	Alloys
Bear Metallurgical Co.	ERAMET Group (France)	Butler, PA	FeMo, FeV
CC Metals & Alloys (CCMA)	E.On AG (Germany)	Calvert City, KY	FeSi
Eramet Marietta Inc.	ERAMET Group (France)	Marietta, OH	FeCr, FeMn, SiMn
Felman Productions Inc.	Privat Group (Ukraine)	New Haven, WV	SiMn
Global Titanium Inc.	Privately held (USA)	Detroit, MI	FeTi
Globe Metallurgical Inc.	Globe Specialty Metals Inc. (USA)	Beverly, OH	FeSi
Metallurg Vanadium Corp.	Advanced Metallurgical Group N.V. (Netherlands)	Cambridge, OH	FeV
Oxbow Carbon and Minerals LLC	Oxbow Carbon and Minerals LLC (USA)	Bridgeport, AL	FeSi
Reading Alloys Inc.	Ametek Inc. (USA)	Robesonia, PA	FeNb
RTI Alloys	RTI International Metals Inc. (USA)	Canton, OH	FeTi
Stratcor, Inc.	Evraz Group S.A. (Russia) and Sojitz Corp. (Japan)	Hot Springs, AR	FeV
Thompson Creek Metals Co.	Thompson Creek Metals Co. (USA)	Langeloth, PA	FeMo

The location and status of these plants are shown on the maps in figures 3 and 4. Some companies have changed ownership, for example, SKW Alloys Inc. became CCMA in 1999 and took over the FeSi operations at Calvert City, KY [31-1999 p. 681]. Another example is the Canadian firm Niobec Co. that had a plant in St. Honore de Chicoutimi, Quebec, producing FeNb. In 1994, Cambior Inc., acquired Niobec and continued to produce FeNb at the Chicoutimi plant.

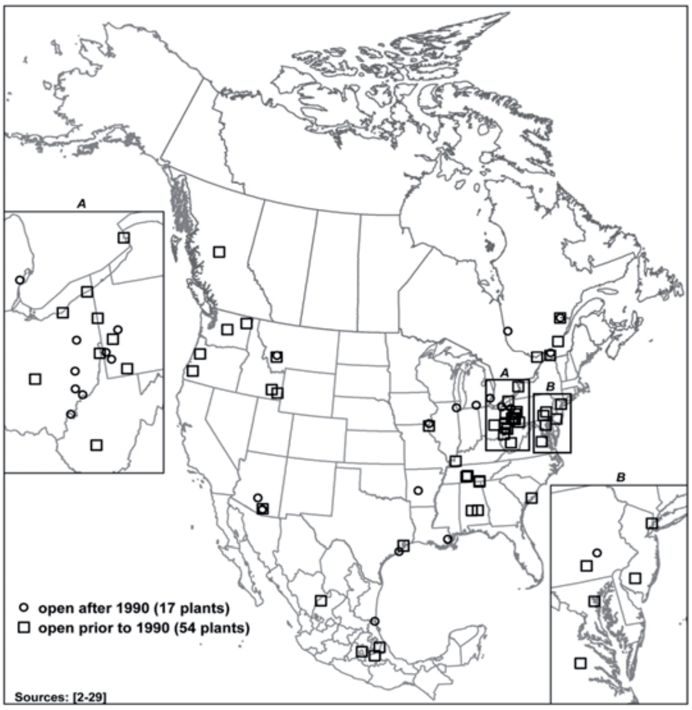


Figure 3: North American ferroalloys plants open prior to 1990 and open after 1990.

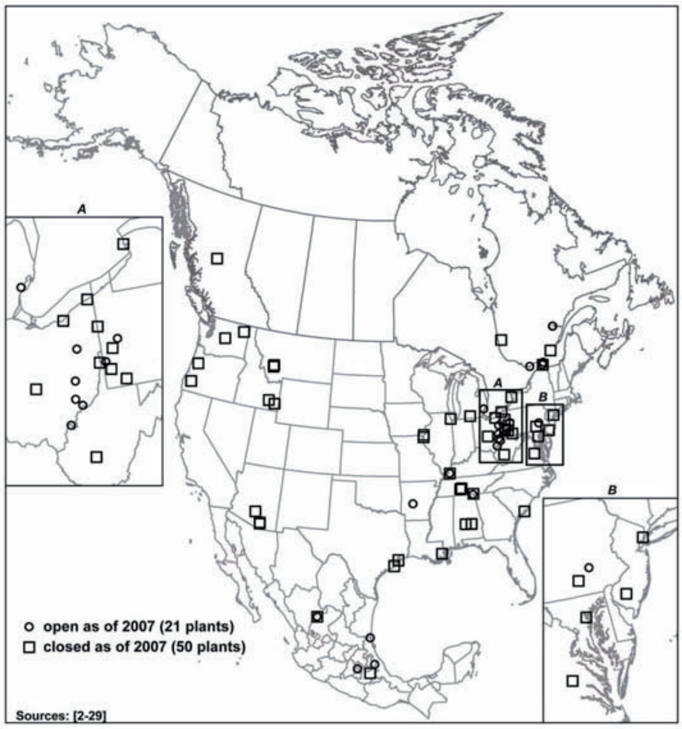


Figure 4: North American ferroalloys plants closed as of 2007 and open as of 2007.

3 TYPES OF NORTH AMERICAN FERROALLOYS PRODUCED

In general, the types of ferroalloys produced in Canada remained fairly consistent from 1987 to 2007. In 2007, the Canadian ferroalloy companies reported production of FeSi, FeMn, FeMo, FeNb, and FeV. Mexican ferroalloy production as of the end of 2007 included FeCr, FeMn, and SiMn. This represents an exclusion of reported production capabilities of FeMo, FeSi, FeTi, FeV, and others. A decrease in the variety of ferroalloys produced was evident in the United States. After 1987, but sometime before 2007, there were at least 26 different ferroalloys being produced, which included a wide range of bulk and non-bulk ferroalloys. As of 2007, the majority of ferroalloy production was focused on bulk ferroalloys, with FeB, FeMo, FeNb, FeTi, and FeV being produced in lesser amounts. This reflects the decline in the number of plants producing ferroalloys. For example, in 1987, there were 11 FeSi plants in the United States, and in 2006, there were only 3 FeSi plants operating in the United States [30-1987, pp. 760], [31-2006, pp. 67.8].

4 NORTH AMERICAN FERROALLOY PRODUCTION

In North America, annual production of ferroalloys has decreased from 1987 to 2007 (Figure 5). In Mexico, the production for 1987 was 267,000 metric tons (t), and in 2007 it was 159,000 t. Production in Canada decreased from 337,000 t in 1987 to 88,000 t in 2007, and in the United States, production fell from 615,000 t in 1987 to 546,000 t in 2007.

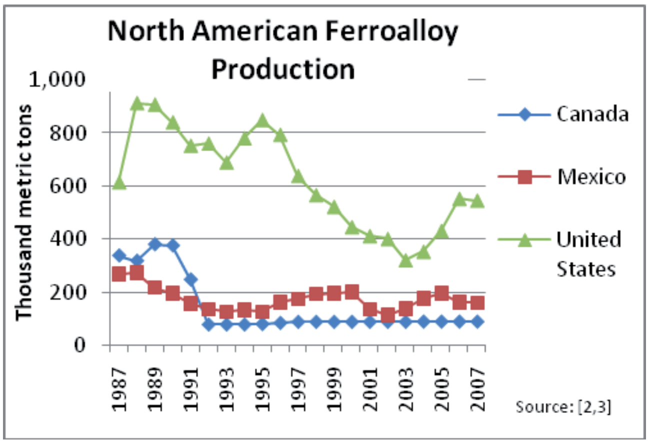


Figure 5: North American ferroalloy production.

World ferroalloy production increased during this same period. NAFTA was enacted in 1994, and most of its articles were enacted by 2007. For analysis, ferroalloy production data were combined for 1987-94, the 8-year period before the enactment of NAFTA (pre-NAFTA), and the 15-year post-NAFTA period, 1995-2007. During the pre-NAFTA period total world production was 144 million metric tons (Mt) with an average annual production of 18 Mt. For the post-NAFTA time period, world production was 291 Mt and average annual production was 22 Mt. Pre-NAFTA Canada produced 1.3% of the total world production, and 0.4% post-NAFTA. Mexico produced 1% in 1987–94 and 0.7% from 1995 to 2007. The United States produced 4.3% for the pre-NAFTA period and 2.4% during the post-NAFTA period (Figure 6).

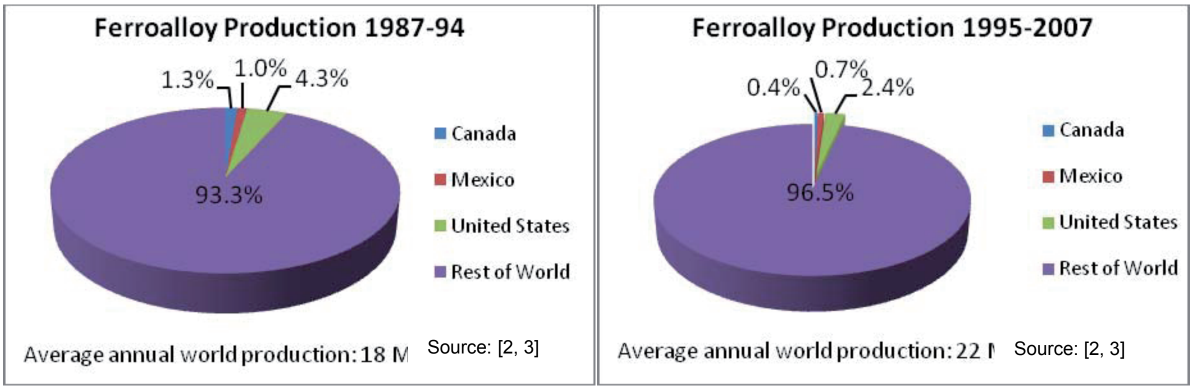


Figure 6: Total ferroalloy production, 1987-94 and 1995-2007.

5 NORTH AMERICAN FERROALLOY EXPORTS

Ferroalloy exports to the world from North America have fluctuated. In the United States, imports and exports of ferroalloys were affected by the increase and subsequent decrease of the ferroalloys holdings in the National Defense Stockpile between 1987 and 2007. Canadian exports have decreased from 1987 to 2007 by 23%, while the exports from Mexico and the United States to the world have risen by 6% and 24% respectively (figure 7).

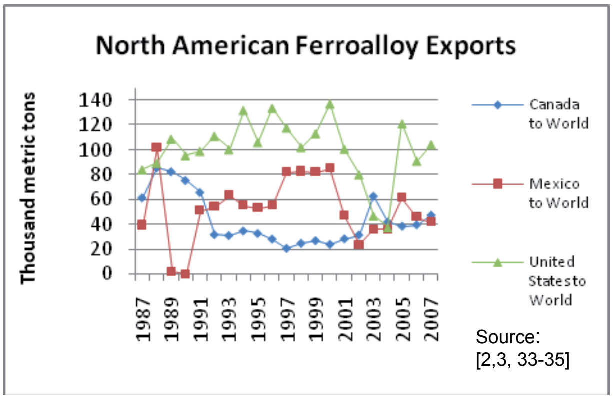


Figure 7: North American ferroalloy exports to the world.

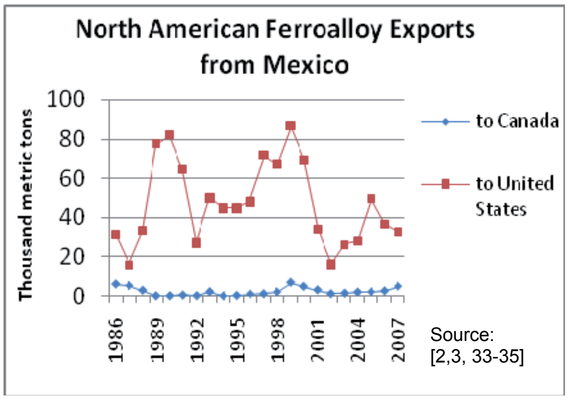


Figure 8a: Trends in Mexican ferroalloy exports.

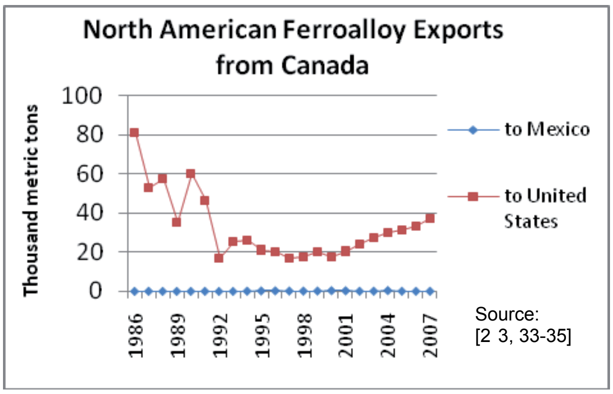


Figure 8b: Trends in Canadian ferroalloy exports.

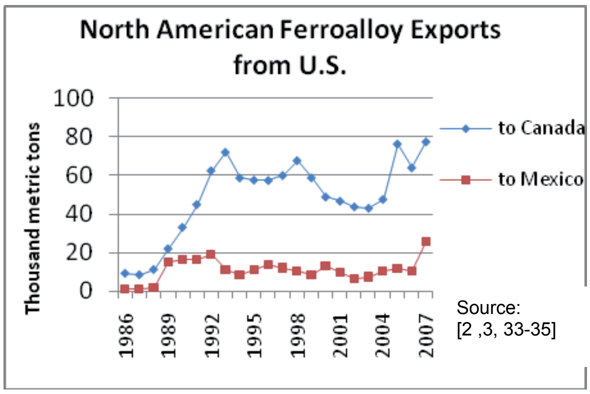


Figure 8c: Trends in U.S. ferroalloy exports.

The trends for ferroalloy exports within North America are illustrated on figures 8a, b, and c. Annual average exports for 1987 through 1994 and 1995 through 2007, by country are shown in Table 2. North American ferroalloy exports. The exports from NAFTA countries to NAFTA countries rose in the 1995-2007 time period in most cases, except for those to the United States. Notably, Canadian exports to Mexico rose to 70 t in 2007 from 14 t in 1987. This could be the result of an increased demand by Mexico for FeSi, which it has not reported producing since 1995.

The percentage change from pre-NAFTA (1987-94) and post-NAFTA (1995-2007).			
Exports	% change [1]	Annual average [1,2,3]	
		1987-94	1995-2007
Canada to Mexico	592%	28	195
Canada to United States	-52%	50,000	24,000
Mexico to Canada	20%	2,100	2,500
Mexico to United States	-12%	53,000	47,000
United States to Canada	42%	40,500	57,600
United States to Mexico	2%	11,500	11,700

1 Data rounded to nearest percent or three significant digits.
2 Data based on available reporting.
3 Metric tons.

6 NORTH AMERICAN BULK FERROALLOYS

Trends in imports, exports, production, and apparent consumption (defined as production + imports – exports; without accounting for stock changes) for bulk ferroalloys—FeCr, FeMn, FeSi, and SiMn—are shown in figure 9.

In Canada and Mexico, imports rose, while exports, production, and consumption generally declined. Canadian production rates declined considerably, while imports rose. Prior to the enactment of NAFTA, production rates in Mexico declined from 1987 rates. However, production seemed to recover post-NAFTA. In the United States the four trade metrics remained fairly consistent, with slight increases and decreases.

In Canada, prior to 1993, production fluctuated with consumption. After 1993, however, imports and consumption appear to be closely related. Before 1993 Canada met consumption needs with domestic production, while after 1993 it relied on imports. This decline in production could be related to the world trend of increased ferroalloy production in ore-producing countries, or perhaps trade agreements, such as NAFTA, made the importation of ferroalloys more cost effective compared to domestic production. In Mexico, production and consumption follow the same trends. Hence, Mexican ferroalloy production appears to change according to domestic consumption. Mexico has a manganese ore source (in the Molango district) and it is conceivable that this raw material source has enabled Mexican ferroalloy production of FeMn and SiMn to be economically feasible. In addition, trade agreements, such as NAFTA, might have helped to sustain the ferroalloys industry in Mexico. Ferroalloy consumption in the United States trends closely with imports. Thus, the United States relies on imports to meet changes in consumption needs.

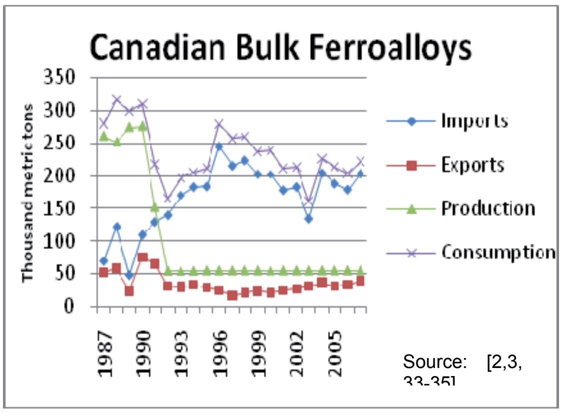


Figure 9a: Trends for North American bulk ferroalloys—FeCr, FeMn, FeSi, and SiMn.

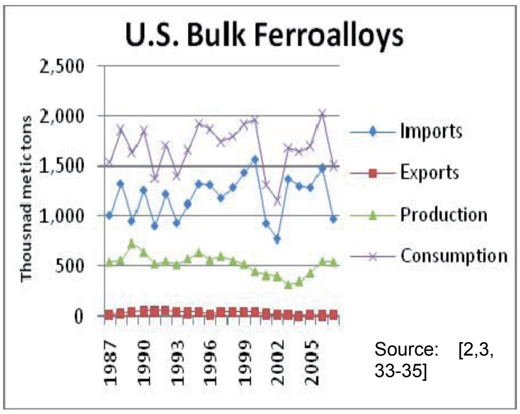


Figure 9b: Trends for North American bulk ferroalloys—FeCr, FeMn, FeSi, and SiMn.

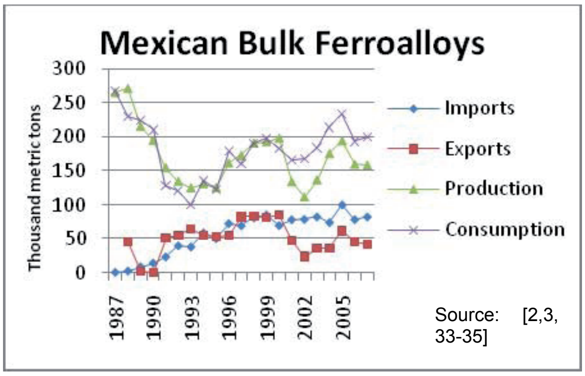


Figure 9c: Trends for North American bulk ferroalloys—FeCr, FeMn, FeSi, and SiMn.

In table 3, annual averages for each of the four criteria were compared for the pre-NAFTA and post-NAFTA time periods. Consumption of bulk ferroalloys decreased in Canada by 9%, increased in Mexico by 4%, and increased in the United States by 5%. Production was similarly evaluated and in all three countries it decreased—Canada by 68%, Mexico by 13%, and the United States by 16%. Conversely, imports of bulk ferroalloys increased in each country as follows: Canada, 61%; Mexico, 228%; and the United States, 14%. Exports decreased for Canada and the United States by approximately 40%, while Mexican exports rose by 65%. Bulk ferroalloy production decreased in North America as imports increased, with increased consumption of bulk ferroalloys outpacing production rates.

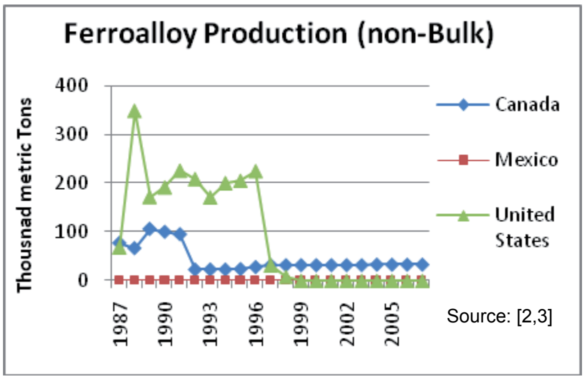
Table 3: Bulk Ferroalloys

The percentage change in bulk ferroalloys from pre-NAFTA (1987-1994) and post-NAFTA (1995-2007). [1,2]			
	Canada	Mexico	United States
Consumption	-9%	4%	5%
Production	-68%	-13%	-16%
Imports	61%	228%	14%
Exports	-41%	65%	-40%

1 The values are based on an annual average for each time period.
2 Data rounded to nearest percent.

7 NORTH AMERICAN NON-BULK FERROALLOYS

Production of the North American non-bulk ferroalloys—FeB, FeMo, FeNi, FeNb, FeTi, FeW, FeV, and others—is presented in figure 10. The combined annual average production rate decreased in Canada and Mexico for post-NAFTA compared with the pre-NAFTA time period. For Canada, the production decreased by 52%, and in Mexico, it declined with no reported production of non-bulk ferroalloys during 1995-2007. As a consequence of declining production, exports of non-bulk ferroalloys decreased for Canada and Mexico by 45% and 98%, respectively. In the United States, from 1997-2007, FeB, FeNb, FeMo, FeP, FeTi, and FeV data were withheld from reported production statistics to avoid disclosing company proprietary information, and there was no reported FeNi production after 1999. As a result, an analysis comparing the change in U.S. production rates of non-bulk ferroalloys can not be adequately performed. However, U.S. non-bulk ferroalloy exports to the world increased by 21% (Figure 11). In Canada, there was a spike of worldwide non-bulk ferroalloy exports in 2003, which possibly can be attributed to selling stockpiled ferroalloys or re-exports.



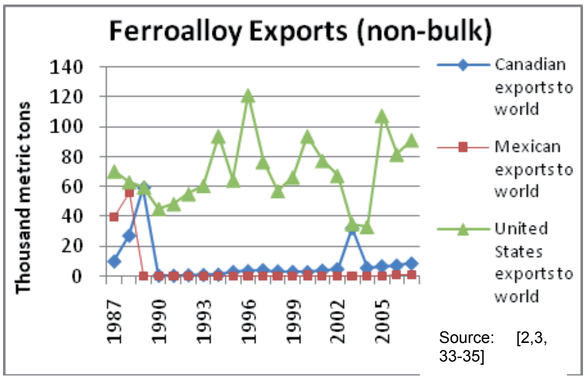


Figure 10: Non-bulk ferroalloy production for North America—FeB, FeMo, FeNi, FeNb, FeTi, FeW, FeV and others. (Note: 1999 onward U.S. data withheld to protect company proprietary information).

Figure 11: Non-bulk ferroalloy exports for North America—FeB, FeMo, FeNi, FeNb, FeTi, FeW, FeV, and others.

8 FERROALLOY INDUSTRY AND TRADE

In order to encourage beneficial trade among nations, trade agreements exist among many countries and groups of countries. Free trade or trade liberalization can facilitate good relations among nations and aid economic growth. However, the imports of low-priced materials can be detrimental to a nation's domestic producers of those materials. As a result, tariffs may be imposed on imports. Antidumping duties are applied to imports that are sold below cost of production in the exporting country. Countervailing duties are imposed on imports that have been found to be subsidized by the exporting country.

In North America, there have been a number of antidumping and countervailing duties imposed on ferroalloys. From 1980 to 2001, U.S. ferroalloy companies brought antidumping suits against a number of countries. Of the 89 petitions, 69 cases resulted in an increase in duties on ferroalloys. Countries affected included Argentina, Brazil, China, Egypt, Kazakhstan, Ukraine, and Venezuela. The new duties assessed ranged from 1.5% to 90% ad valorem. For example, producers in the United States petitioned for an increase in countervailing duties against FeSi imports from Venezuela in 1992, owing to accusations of subsidized imports sold below cost of production; four more cases, including a case against FeCr imports from South Africa, resulted in increased duties ranging from 5% to 22% ad valorem. In Mexico, there were two antidumping cases in 2002; one against FeMn imports from China, which resulted in an increase in the duty to 55% from 42% ad valorem. The second case was against FeSiMn imports from Ukraine that increased the import duty to 50% from 18% ad valorem [36].

9 FERROALLOY PRICING

The price of ferroalloys is dependent on many factors, which include raw material prices, raw material and ferroalloy transportation, and energy and labor costs. In addition, price can be used as a means to trace changes in supply and demand and that of political stability. Beginning in the 1970s, energy costs began increasing, which directly affected ferroalloy prices. Also, starting around the same time, costs for installing additional pollution control equipment increasingly became a factor affecting both production costs and price. In the 1980s, FeSi and SiMn prices rose owing to increased consumption by the steel industry. Oversupply of these commodities later led to decreases in prices by 1990. These price decreases resulted from earlier increased demand that led to higher production rates throughout the world, especially in South America, China, and the Soviet Union.

The dissolution of Soviet Union in 1991 resulted in an oversupply of some ore used in ferroalloy production owing to the sale of stockpiled material. As well, the dissolution of the Soviet Union increased the number of ferroalloy producers competing in the world market, as successor republics were able to engage in trade more freely. Both of the above factors could have led to a decrease in price. In 1993–94, lower prices resulted in U.S. companies pursuing antidumping laws in order to compete with imports priced below U.S. production costs. A peak in prices occurred again in 1996 owing to increased steel production. Following this price peak, the prices again declined coincident with the weakening economic environments in Asia and Russia. Another factor affecting the earlier decreasing prices might have been the introduction of new technologies that allow for high-quality steel production utilizing smaller quantities of ferroalloys. This was specifically the case with ferromanganese [37] [38].

10 FERROALLOY PRODUCTION POWER COSTS

Costs of power and reducing agents combined in the ferroalloys industry can be as high as 50% of the production cost [39], and can have considerable effect on the industry [40]. Increased power costs may have been a significant factor in the declining number of North American plants during the last 20 years. The merging of producers in the ferroalloys industry with upstream producers, such as mining and power industries has enabled some ferroalloy producers to reduce production and supply costs [40]. In Canada, Elkem Metal Canada Inc. built its own hydroelectric power plant to supply approximately 80% of the power to its Chicoutimi plant. The plant has a FeSi production capacity of 40,000 t/yr. Approximately 70% of the output from Elkem's Chicoutimi plant was exported to the United States in 2006 [41]. Elkem also operated a hydroelectric plant for its FeSi operation in Alloy, WV (now owned by Globe Metallurgical Inc.) [42].

11 FERROALLOY CONSUMERS AND END USE

The leading consumer of ferroalloys is the steel industry, which is continually improving techniques for producing higher quality steel. The demand for high-quality steel was not expected to abate in the near future, but in some cases these improved techniques may result in a decrease of the quantity of ferroalloys needed [31-2005, pp. 26.3-26.4]. There are other products, such as plastic, that can, in some cases, replace the steel used in consumer products. Since ferroalloys are used primarily in steel manufacture, the actual end uses are numerous, such as in the construction of buildings, cars, household goods, and in the aerospace industry.

12 FERROALLOY INDUSTRY SUSTAINABILITY

Rising costs in North America associated with environmental compliance have led some ferroalloy plants to close, or reduced some plants' profit margins. This is especially true in the United States, where as much as 20% of ferroalloy plant expenses are related to environmental controls. Most European ferroalloy producers also have stringent environmental standards to follow; however, other countries may not follow or meet standards as stringent [43]. The challenge for the North American ferroalloy industry is to absorb costs for new environmental technologies while still remaining competitive on a price basis in the world market.

13 CONCLUSIONS

In North America there has been a decline in ferroalloys production. The number of operating companies and plants has decreased, and there has been a steady decrease in ferroalloy production while overall world production has increased. The changes to the ferroalloy industry in North America can be attributed to a number of factors including the shift of ferroalloy production to the ore-producing countries. This trend was clearly observed by the 1980s, but as early as 1970, production of FeCr in the United States began to decrease, and consequently imports rose [44]. Increased global competition appears to be the overall reason for the decline of the North American ferroalloys industry.

NAFTA does appear to have had a positive influence on ferroalloys trade among the North American countries, which is evidenced by a percentage increase in trade in all cases, except for imports into the United States from Canada and Mexico. However, the Canada – United States Free Trade Agreement of 1987 was already implemented and any positive results of NAFTA between Canada and the United States could be attributed to this trade agreement. In addition, in Mexico, a movement of economic liberalization began in the 1980s. This included Mexico's membership in the General Agreement on Tariffs and Trade in 1986, which reduced import duties and consequently encouraged trade liberalization [45]. As a result, further analysis would need to be conducted to more accurately assess the effect of NAFTA on the ferroalloys industry in North America.

14 REFERENCES

[1] McGannon, H.E., Ed., “The making, shaping and treating of steel”, Herbick & Held, 1971, pp. 256-258.
[2] U.S Bureau of Mines, “Minerals yearbook 1987-1994”, Department of the Interior, 1989-1996.
[3] U.S. Geological Survey, ‘Minerals yearbook 1995-2007”, Department of the Interior, 1997-2009.
[4] Davies, S., “Ferro-alloy directory & databook”, Metal Bulletin Books Ltd., 1993, pp. 15-17, 49, 71-81.
[5] Sexton, S., “Ferro-alloy directory and databook”, Metal Bulletin Books Ltd., 1996, pp. 14-18, 69-70, 97-105.
[6] Wood, E. and Kusel, P., “Ferro-alloy directory and databook”, Metal Bulletin Books Ltd., 1998, pp. 14-17. 76-78, 106-116.
[7] Wood, E. and Owen, M., “Ferro-alloy directory”, Metal Bulletin plc, 2005, pp. 13-16, 68-69, 90-97.
[8] Ashland, 2009. (Accessed July 27, 2009, at http://www.ashland.com.)
[9] Bear Metallurgical Company, 2009. (Accessed August 26, 2009, at http://www.bearmet.com/.)
[10] BPI industrial minerals supplier, [undated]. (Accessed August 26, 2009, at http://www.bpiminerals.com/by-product-processors.htm.)
[11] BusinessWeek, 2009, Cambior Inc. (Accessed August 11, 2009, at http://investing.businessweek.com/research/stocks/private/snapshot.asp?privcapID=353310.)
[12] CCMA CC Metals and Alloys, LLC, 2006. (Accessed August 25, 2009, at http://www.ccmetals.com/.)
[13] Chemalloy, 1999. (Accessed August 5, 2009, at http://www.chemalloy.com/.)
[14] Chemical Online, Atomergic Chemetal Corporation, 2009. (Accessed August 25, 2009, at http://www. Chemicalonline.com/storefronts/atomergic.html.)
[15] Dow Corning Corporation, 2009. (Accessed August 10, 2009, at http://www.dow.com/.)
[16] Globe Specialty Metals, 2009. (Accessed August 26, 2009, at http://www.glbsm.com/.)
[17] Goldman Titanium, [undated]. (Accessed August 10, 2009, at http://www.goldmanti.com.)
[18] Goliath company profiles, 2009, Umetco Minerals Corp. (Accessed August 11, 2009, at http://goliath. ecnext.com/coms2/product-compint-0000208790-page.html.)
[19] Gulf Chemical & Metallurgical Corporation An Eramet Group Company, 2009. (Accessed September 3, 2009, at http://www.gulfchem.com/.)
[20] H.C. Stark, 2007, Empowering high tech materials. (Accessed August 10, 2009, at http://www.hcstark.com/index.php?page_id=5/.)
[21] Inco special products. 2003. (Accessed August 10, 2009, at http://www.novametcorp.com/library/.)
[22] Minera Autlan, 2005. (Accessed August 11, 2009, at http://www.autlan.com.mx/.)
[23] Molycorp Minerals, 2009. (Accessed August 26, 2009, at http://www.molycorp.com/.)
[24] Reading Alloys advanced engineering materials, 2009. (Accessed August 26, 2009, at http://www. Reading-alloys.com/04.html.)
[25] Stratcor, 2007. (Accessed August 11, 2009, at http://www.stratcor.com/.)
[26] Teledyne Technologies Incorporated, 2008. (Accessed August 10, 2009, at http://www.teledyne.com.)
[27] Thompson Creek, 2009. (Accessed August 11, 2009, at http://wwwthompsoncreekmetals.com/.)
[28] Timminco, 2009. (Accessed August 11, 2009, at http://www.timminco.com/.)
[29] Union Carbide Corporation, 2009. (Accessed August 10, 2009, at http://www.ucarbide.com/products/Index.htm.)
[30] [U.S Bureau of Mines, “Minerals yearbook, 1987, 1988, 1989, 1990, 1991, 1994”, Department of the Interior, 1989, pp. 360, 760; 1990, pp. 845; 1991, pp. 405; 1993, pp. 432, 448-9; 1993, pp. 1375; 1996, pp. 681.
[31] U.S. Geological Survey, “Minerals yearbook, 1999, 2005, 2006”, Department of the Interior, 2001, pp. 681; 2007, pp. 26.3-26.4; 2009, pp. 67.8.
[32] U.S. Department of Defense, “Requirements for and administration of the ferroalloy upgrade Program,” 1994, no. 94-034, pp. i, 1-2.
[33] [Statistics Canada, “Canadian international merchandise trade”, 2009. (Accessed June 1 – August 31, 2009, at http://www.statcan.gc.ca/trade/scripts/trade_search.cgi.)
[34] United Nations Commodity Trade Statistics Database, “UN Comtrade Database”, 2009. (Accessed June 1 – August 31, 2009, at http://comtrade.un.org/db/default.aspx.)
[35] United States International Trade Commission, “Interactive Tariff and Trade Dataweb”, 2009. (Accessed June 1 – August 31, 2009, at http://www.usitc.gov/.)

[36] Blonigen, B., “U.S. antidumping and countervailing duty data and links”, 2006. (Accessed July 24, 2009, at http://www.uoregon.edu/~bruceb/adpage.html.)
[37] Jones, T.S., Manganese, *in* Plunkert, P.A., and Jones, T.S., comps., “Metal prices in the United States through 1998”, U.S. Geological Survey, 1999, pp. 83-85.
[38] Jones, T.S., Silicon, *in* Plunkert, P.A., and Jones, T.S., comps., “Metal prices in the United States through 1998”, U.S. Geological Survey, 1999, pp. 135-138.
[39] Daavittila, J., Honkaniemi, M., and Jokinen, P., “The transformation of ferrochromium smelting”, Proceedings of the Tenth International Ferroalloys Congress, 2004, pp. 432-443.
[40] Song, J., and Kang, G., “A practice of ferroalloy production in an “environment-friendly and recycling” Way”, Proceedings of the Tenth International Ferroalloys Congress, 2004, pp. 705-711.
[41] Elkem S A, “Elkem Chicoutimi”, 2007. (Accessed June 3, 2009, at http://www.foundry.elkem.com.)
[42] Embassy of Norway, “Norwegian companies in USA – 12”, 1996. (Accessed July, 30, 2009, at http://www.norway.org/News/archive/1996/199604elkem.htm.)
[43] Cohn, L.M., “US ferroalloy makers find costs to clean up emissions very high; new federal regulations on producers expected by early 1995”, American Metal Market, 1995, v. 102, no. 2, pp. 7.
[44] Papp, J.F., Chromium, *in* Plunkert, P.A., and Jones, T.S., comps., “Metal prices in the United States through 1998”, 1999, U.S. Geological Survey, pp. 25-29.
[45] Congressional Budget Office, “The effects of NAFTA on U.S.-Mexican trade and GDP”, 2003. (Accessed September 22, 2009, at http://www.cbo.gov/doc.cfm?index=4247&type=0&sequence=0.)