

COMPREHENSIVE STRATEGIC ANALYSIS OF THE TANTALUM INDUSTRY

by

Joel JEANGRAND

PROJECT SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF BUSINESS ADMINISTRATION

In the
Faculty
of
Business Administration

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SIMON FRASER UNIVERSITY



Summer 2005

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APPROVAL

Name: **Joel Jeangrand**

Degree: **Master of Business Administration**

Title of Project: **Comprehensive Strategic Analysis of the Tantalum Industry**

Supervisory Committee:

Senior Supervisor
Mark Selman, Adjunct Professor

Second Reader
Neil Abramson, Associate Professor

Date Approved:

August 11, 2005



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ABSTRACT

This thesis reviews in detail the niche industry of tantalum production. The author explores the multiple uses and consumption trends of this metal from its main characteristics to its complex value chain. The purpose of this paper is to analyze the dynamics taking place in the tantalum industry today and provide the reader with a strategic understanding thereof. The analysis leads to conclusions about the general attractiveness of the industry, segmented or as a whole. Tantalum raw material may face a shortage of supply in the near future which could lead to profitable investment opportunities. The paper makes some recommendations to existing players and also offers a general framework for prospective entrants.

DEDICATION

I dedicate this project to my lovely wife. Only her undying support and encouragement allowed me to reach and clear this last hurdle of my program. Long were the hours spent reading, learning and typing in front of my computer while she was taking over the many tasks of our family life. Thank you Coco.

ACKNOWLEDGEMENTS

I would like to thank my three wonderful children: Caitlin, Alexia and Zachary for their support and patience during these past two years.

A special thank you goes to the members of my study group the WEMBA MEMBAS, otherwise known as the “Keeners”: Marnie Larson, Craig Slack, Randy Crighton and Lorna Young. We all connected from the first minute we met and I hope that these bonds will not be soon forgotten.

Thank you as well to Bill Coleman for taking me on board the day the program started at Coleman Associates Consulting and for providing flexibility in the workplace which allowed me to complete my studies.

Thank you to Gary Jones for his valued guidance and to Keith Low for giving me access to Teck Cominco’s library.

Finally, I would like to thank Dr. Selman and Dr. Abramson for their help and constructive comments.

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GLOSSARY

Capacitor	Two conductive plates separated by an insulator, or dielectric which is tantalum pentoxide (Ta ₂ O ₅) in a tantalum capacitor. Capacitors are electronics components that store, filter, and regulate electrical energy and current flow and are one of the essential passive components used on circuit boards.
Capacitance	Measure of amount of electrical charge stored in a capacitor
Conductor	A material with very low resistance to electricity, like most metals.
Coltan	Short name given to alluvial placer deposits of columbite-tantalite containing 10-40% Ta ₂ O ₅ mostly located in the Democratic Republic of Congo (DRC)
Microfarad (μF)	Most common unit of capacity for tantalum capacitors
Pegmatite	Form of igneous rock consisting of extremely coarse granite resulting from the crystallization of magma rich in rare elements such as uranium, tungsten and tantalum
Sintering	To coalesce under the influence of heat, without actually liquefying.
Solid tantalum	A sintered tantalum pellet with a solid counter electrode
Sputtering targets	Piece of metal on which energetic ions are bombarded to eject atoms into the gas phase. Commonly used for thin-film deposition.
Ton	Metric ton or 1000 kilogram
Wet tantalum	A sintered tantalum pellet in a liquid acid electrolyte as compared with solid tantalum.

1 INTRODUCTION

1.1 Context

The mining industry around the world is currently enjoying unprecedented consumption levels contributing to strong and often record high metal prices. In this positive context, there is one exception. Demand for a unique metal called tantalum has remained stable during these past years and as a result prices have been moderate.

On Aug. 30th 2004, Sons of Gwalia (SOG), one of Australia's oldest mining houses, went into voluntary financial administration after discovering that its mines might not have enough gold left to meet its gold hedge commitments and finance its foreign exchange exposure. Its 2004 liabilities totalled about US\$700 million¹ against operating revenue of US\$420 million. Although hedging in its gold division led the company to bankruptcy, its advanced material division, which includes a majority of tantalum mining, is profitable and operates satisfactorily according to available public information. SOG happens to be the world's largest producer of tantalum concentrate and controls about 65% of the world supply.

Teck Cominco, based in Vancouver and one of Canada largest mining houses, used to own about 9% of SOG's capital until it wrote down this investment in September 2004 by US\$43 million. Teck Cominco is now exploring strategic options related to this industry and the opportunities surrounding this unique metal.

¹ All dollars quoted throughout the work are American dollars

1.2 Scope

Chapter 2 reviews the main characteristics of the industry from assessment of mining resources to a review of the tantalum supply/demand balance. It provides detailed statistics on resources, reserves and concentrate production by owner, producer and country plus an overview of the complex conversion of tantalum ore into finished product. Chapter 3 describes the industry value chain and its various participants including: explorers, miners, processors, producers, integrators and recyclers. Chapter 4 describes the main uses of tantalum. The cyclical electronics sector dominates the consumption of tantalum but there are new promising applications such as sputtering targets and medical implants. The study also focuses the respective growth rates of various consuming sectors. Chapter 5 focuses on analysing the two key segments within this full industry analysis - tantalum miners and tantalum processors. Michael Porter's model is used to capture the various forces and give a general industry assessment. Finally, Chapter 6 provides recommendations for current and prospective industry participants.

2 MAIN INDUSTRY CHARACTERISTICS

2.1 What is Tantalum?

Tantalum is one of the less abundant metals on our planet. It belongs to the category of “refractory” metals which can sustain high temperatures and resist corrosion by acids. This metal was discovered by a Swedish researcher Anders Gustaf Ekeberg in 1802. He found this new element by analyzing mineral samples coming from Scandinavia. The name tantalum comes from Tantalus, the son of Zeus in Greek mythology, and was chosen because of the “tantalising” challenge of defining the chemical nature and other properties of this new element. The first actual commercial application took place in 1905 with the invention of metal filaments in incandescent light globes which were soon replaced in 1909 by tungsten. Tantalum is hard, dense and blue-grey in colour with a melting point of almost 3000°C. It has high tensile strength, is very malleable and ductile, and almost completely immune to chemical attack. Tantalum is also a good conductor of heat and electricity and due to its capacity to store and release an electrical charge; it is widely used in the electronics sector.

2.2 Mineralogy

Tantalum exists in nature exclusively as an oxide. The main source of tantalum is a series of minerals that contain niobium (also called columbium), iron, titanium, manganese, and tantalum oxides. Tantalum and niobium have very strong geochemical affinity and are very often found in the same deposits. The most commonly mined is tantalite-columbite or also called tantalite or tantalum pentoxide (Ta_2O_5).

There are two main types of deposits which host tantalite: placer or hard rock. Placer deposits are sediments showing an enriched level of heavy minerals including tantalum. In the majority of cases, these deposits have been subjected to deep weathering processes for long periods. Because of tantalite's high specific gravity of 8.1, minerals are concentrated as stream channel sediments. They are fairly accessible and take half the time to develop compare with hard rock deposits. Unfortunately placer deposits are fairly rare and not commonly present in Canada but are located in many central African countries, particularly the Democratic Republic of Congo. In this area, tantalite ore with high concentration levels is recovered by artisanal mining operations.

Hard rock deposits are the most common and today are the main source of ore supply to the industry. To simplify, there are three main types of hard rock deposits: pegmatites, granites and carbonites. Ore bodies are made up of different types of rocks which are themselves made up of various minerals. As an example, quartz as a mineral is a major part of granite, a rock. In the case of tantalum the most common rock formation which hosts the current tantalum ores is called pegmatite. Pegmatite hard rock deposits are the dominant source while carbonites (or alkaline complexes) are rare. The only production of tantalum so far has been from pegmatites and specialty granites. Mines are mostly open pit operations but there are also some underground mines when the ore grade is high enough. It takes about 3 to 5 years to develop a green-field tantalum mine from geological discovery to first concentrate production. At times of high prices such as in 2000, a number of carbonite occurrences became potential tantalum/niobium exploration targets. In some deposits (Western Australia or British Columbia), tantalum would be the main target but in many cases tantalum is a by-product of niobium mining.

While compared to other ores, tantalum metal contained in ore is very small and ranges from 0.02 to 0.1%. This would translate into a range of 200 grams per tonne to 1000 grams per tonne which is almost equivalent to the concentration levels in precious metal ores. The quality of

ores varies as well in levels of impurities. Both ore concentration and presence of impurities can influence the ore beneficiation costs. In some rare cases, tantalum ores may also include other valuable minerals (e.g. niobium, tin, spodumene for lithium production) which could be valuable by-product. It falls to the expertise of the processor to separate out tantalum and other valuable minerals. Tantalum also often contains radioactive traces which is a growing concern for transportation.

2.3 Mineral resources and reserves

As a reminder to the reader, a mineral **reserve** is the economically minable part of a mineral **resource** demonstrated by a pre-feasibility study at a minimum. Both terms are used to describe tantalum mineral currently underground.

About 25 years ago, the majority of tantalum produced was a by-product of the mining of tin ores but this is no longer the case. Today about 70% of mining and mineral processing of tantalum stands alone. As described in Table 1, there is about 150,000 tons of tantalite contained in ores from resources around the world. Australia hosts the largest share but other substantial deposits have also been found recently in Saudi Arabia, Egypt, Canada (NWT), Greenland, and Asia (China).

These resources may or may not ever be mined. For this reason it is more appropriate to look at tantalum reserves.

Today reserves amount to almost 53,000 tons at existing mines as shown in Table 2. The bulk of reserves are in Australia with about 43,000 tons. This figure however is incomplete because data from many African nations as well as from Brazil are missing. There are no precise reported reserves evaluations that have been established for African deposits although some of these countries have been producing for more than 40 years. Tantalum grades available in Brazil

Table 1 - Inventory of historical tantalum resources (non-producing in 2005)

Name	Country	Owners	Resources	Ta ₂ O ₅ Grade	Contained Ta ₂ O ₅
Mt Weld	Australia	Anaconda Nickel	273,000,000	0.015%	40,950
Dubbo	Australia - NSW	Alkane Exploration	83,000,000	0.027%	22,410
Location 801	China	Ningxia Non-Ferrous Metals	121,500,000	0.018%	21,870
Thor Lake (Lake zone)	Canada - NWT	Avalon Ventures	70,000,000	0.03%	21,000
Motzfeldt Intrusion	Greenland	Angus & Ross	50,000,000	0.03%	15,000
Baerzhe	Inner Mongolia, China	Luan Mining Co. Ltd	37,000,000	0.022%	8,140
Morrua	Mozambique	30% Cabot/36% Madal Group	7,500,000	0.070%	5,250
Marropino	Mozambique		22,000,000	0.019%	4,180
Udegi Area	Nigeria	Quilos International	7,200,000	0.04%	2,880
Abu Dabbab	Egypt	Gippsland Ltd. And Govt in 50/50 JV	7,280,000	0.025%	1,820
Muiane	Mozambique		7,000,000	0.016%	1,120
Blue River/Verity	Canada - BC	Commerce Resources	3,800,000	0.023%	874
Tantalite Valley	Namibia	Severin Mining	2,500,000	0.03%	748
Kougarok	US	60% Chapleau/40% Navigator	2,700,000	0.020%	540
Coto Tocayas	Spain	Solid Resources	3,500,000	0.012%	420
Uis tin Tailings	Namibia	Central African	5,000,000	0.008%	400
Rosendal	Finland	Tertiary Minerals	1,300,000	0.029%	377
Cattlin Creek	Australia - WA	Haddington/Sons of Gwalla	363,000	0.052%	189
Binneringie	Australia -WA	50% Tantalum Australia/50% Kemet	440,000	0.0257%	113
Pilgangoora	Australia	Kanowna Lights	400,000	0.005%	20
Bynoe	Australia - Northern Territory	Julia Corp.	140,000	0.013%	18
Marlison Phosphate	Canada - Ontario	MCK Mining/Batic Resources	113,000,000		
Brockman	Australia - WA	Former JV between West Coast Holdings	22,600,000		
Kamativi tin mine	Zimbabwe	Allied Mining Investments	20,000,000		
Three Aloes	Namibia	Camec (Central African Mining & Exp.			
Separation Rapids	Canada - Manitoba	Avalon Ventures			
Waiwa	Australia	50% Tantalum Australia /50% Kemet			
Lilypad Lakes	Canada - Ontario	Avalon Ventures			
Case	Canada - Ontario	Platinova A/S			
Caicara	Brazil	First Choice Industried			
Manono Pegmatite	DR Congo				
De Ruste	Namibia				
Swanson	Namibia				
Erongo	Namibia	Reefion Mining			
Nyanga	Uganda	Uganda Gold Mining			
Benson	Zimbabwe	Allied Mining Investments			
		TOTAL	861,223,000	0.02%	148,319

Data source: TECK COMINCO Commodity backgrounder – July 2002

are mostly available from tin smelting and reserves have not been estimated. Concentrate production is known and reported but reserves figures are only known to be substantial especially in the Amazonas State of Brazil.

At the current rate of consumption (about 2000 mt per year), there are sufficient reserves for at least 26 years of annual consumption and resources for about 74 years. In comparison with other commodities and given the size of its resources, tantalum is a more dependable raw material than oil (35 years) or copper (63 years) with the later widely used in the electronics industry as well. Although under receivership, the still operating Australian company Sons of Gwalia (SOG) holds a commanding position in the industry with about 80% of the world's production from two mines, Greenbushes and Wodgina which are located in Western Australia. Tantalum mineralization has also been reported in 17 countries on the African continent. Central African countries such as Rwanda, Congo, and Uganda have been significant suppliers of high grade tantalum ores. Unfortunately details related to exact locations of deposits and productions figures are very limited. As shown in Table 3, an annual estimate of 300 tons containing Ta₂O₅ is supplied from 8 African countries but there are no reserves estimates available. It is also interesting to note that tantalum mining helps to finance civil unrest in countries like the Democratic Republic of Congo (DRC). Rebels from neighbourhood countries, like Rwanda, have been involved in the mining industry of very high grade tantalum ore. The UN intervened to stop this trade and put pressure on western world buyers. At today's prevailing low prices, this intervention appears to have had some influence in reducing this illegal supply source.

2.4 Supply

Tantalum supply comes either from mines (primary source) or from secondary sources such as recycling, synthetics or strategic military stock. The total estimated supply for the market

Table 2 – Tantalum Reserves 2004

Name	Location	Ownership	Reserve (tonne)	Ta ₂ O ₅ Grade	Ta ₂ O ₅ contained
Congo, Mozambique + 5 countries	Africa				
Wodgina	Australia	100% Sons of Gwalia	63,500,000	0.0370%	23,200
Greenbushes	Australia	100% Sons of Gwalia	88,600,000	0.022%	20,000
Bald Hill	Australia	Haddington/Sons of Gwalia	1,135,699	0.048%	544
Dalgaranga	Australia - WA	Tantalum Australia	170,000	0.032%	54
Nazareno	Brazil	Fluminense (Metallurg sub)			
Pitinga tin mine	Brazil	100% Mamore (Grupo Paranapanema sub.)			
Nanping	China, Fujian	Nanjing Tantalum-Niobium Mining Co.	14,100,000	0.03%	4,230
Yichun	China, Jiangxi	Ningxia Non-Ferrous Metals	36,756,757	0.019%	6,800
Kenticha	Ethiopia	Midroc (Gov't)			
Lac du Bonnet, Bernic Lake	Manitoba	100% Tanco	2,100,000	0.10%	2,100
Nigerian Mining Corp	Nigeria	State-owned & artisanal			
	TOTAL		204,262,456		54,828

Table 3 - Tantalum primary production by producer 2004

Name	Location	Production Tonnes Ta ₂ O ₅
Wodgina	Australia	635
Greenbushes	Australia	415
Congo, Mozambique + 5 countries	Africa	300
Nazareno	Brazil	200
Pitinga tin mine	Brazil	128
Lac du Bonnet, Bernic Lake	Manitoba	82
Kenticha	Ethiopia	68
Bald Hill	Australia	66
Yichun	China, Jiangxi	54
Dalgaranga	Australia - WA	50
Nanping	China, Fujian	45
Nigerian Mining Corp	Nigeria	20
		2,063

Data source: TECK COMINCO Commodity backgrounder – July 2002

was 2,960 tons containing Ta₂O₅ in 2004 (see table 4). At an average price of \$33 per lb (or \$15,000 per ton), the size of this market is only \$44 million.

Table 4 – Tantalum supply 2004

Estimates Year 2004	tons of Ta₂O₅ contained	Share
Australia	1,166	39%
Brazil	328	11%
Part of Africa	320	11%
China	99	3%
Canada	82	3%
Ethiopia	68	2%
Primary source (mineral)	2,063	70%
Recycling	625	21%
DLA	227	8%
Low grade Tin slag	45	2%
Secondary source	897	30%
TOTAL	2,960	

Data source: USGS & Tantalum and Niobium International Study Center (TIC) statistics - 2004

2.4.1 Primary source

Australia dominates the market with the largest single producer, Sons of Gwalia and two smaller Western Australian producers called Haddington Resources and Tantalum Australia. Brazil is the distant second largest producing country with supply coming mostly from the Metallurg owned mine as well as the Paranapanema site. Africa is also a substantial supply source and tantalum mineralization has been reported in this naturally resource rich continent. Central African countries such as the Republic Democratic of Congo (DRC), Uganda, Burundi, and

Rwanda have been significant suppliers of tantalum concentrate for the last several decades. China is also part of the supply picture with 3% coming mainly from two mines along with several smaller operations. Canada, once the largest supplier, now accounts for only about 3% of the total supply. The Canadian mine in Manitoba called TANCO is owned by the largest tantalum processor CABOT and is the only tantalum underground mine operating in the world.

It is also interesting to note that tantalum miners in industrialized nations like Australia and Canada have built ore processing plants which are large and capital intensive. In comparison, developing countries in Africa and Brazil have smaller and simpler facilities meeting the social need of providing local employment. While small operations have seen their high grade, widely accessible ore depleting, large operations like SOG have gained market share thanks to their sourcing reliability.

2.4.2 Potential new primary source

The price surge of 2000-2001 might have increased substitutions but it has also clearly provided valuable information that has contributed to a much more accurate picture of the primary sources of tantalum. Table 5 summarizes potential concentrate productions.

There are several projects around the world which could affect the tantalum industry supply picture and this section will explore them in detail. A distinction has to be made between the expansions of existing mine sites (sometimes called “brownfield projects”) and development of new mines (or “greenfield sites”).

Table 5 – Potential tantalum concentrate production – June 2005

<u>Name</u>	<u>Location</u>	<u>Ownership</u>	<u>Production Type</u>	<u>Ta₂O₅ tonnes produced</u>
Gippsland Ltd.	Egypt	50% JV Gippsland Aus. 50% Egypt Gov.	Ta concentrate	290
Ghurayyah	Saudi Arabia	100% Tertiary Minerals Plc	Ta concentrate	270
Xinjiang	China	100% Xinjiang Western Tantalum Works	Ta concentrate	14
Thaisarco	Thailand	Thaisarco	tin slags	20
Malaysia Smelting	Malaysia	Malaysia Smelting	tin slags	25
Etaginskoye Field	Russia	Zabaikalsky GOK	byproduct of tin	40
Ulba Metallurgy Plant	Kazakhstan	KazAtomProm	byproduct of uranium	25
Lovozerskoye	Russia	Sevredmet JSC	loparite	38
Orlovsky	Russia	Menatek		
Total				722

Data source: TECK COMINCO Commodity backgrounder – July 2002

Australia

Sons of Gwalia's Greenbushes operation located in South West Australia has received the approval, in November 2004, to spend \$8 million to dig an underground extension providing an additional capacity of 500,000 lbs or 227 tons of Ta₂O₅. This project is scheduled to take 18 months. Additional funds of \$6.5 million have also been approved to expand the capacity of its Wodgina mine in the North-West of Australia. The increase of 100,000 lbs (45 tons) will take the mine capacity to 1.4 million lbs (635 tons). Since 2003, the Wodgina mine has become the largest tantalum mine in the world.

Tantalum Australia operates its Dalgaranga mine and ships ore to its dressing plant at another location complemented with ore sourced from Africa when necessary. The company has options on several projects including the Walwa deposit in Western Australia. Projects were developed as joint ventures with Kemet which since has become a lot less active in trying to secure sources of raw materials. Kemet is now simply a passive shareholder. This company is also studying the take over of Sons of Gwalia assets (company web site Dec. 2004).

Haddington Resources's Bald Hill project produces about 60-70 tons of Ta₂O₅ contained per year and the company is looking to expand through exploration in the Northern Territories of Australia.

Egypt:

Gippsland Limited, an Australian junior mining company, is working on a 40 million tons open-pit Egyptian Abu Dabbad tantalum project. The projected initial production of tantalum concentrate based on a bankable feasibility study is 500,000 tons out of which 290 tons of Ta₂O₅ could be produced. The required capital investment is about A\$80 million. The construction start up has been postponed several times due to a lack of financing and the latest announced new start

is scheduled for the second quarter 2006. Co-production of tin and ceramic feldspar will provide additional revenues. Tantalum Egypt is the holding company jointly owned 50% by Gippsland and 50% by the Egyptian government.

Canada:

One of the most active tantalum explorers in North America called **Commerce Resources** is based in Vancouver. This company is working on several tantalum carbonite projects located in British Columbia. They are called Fir and Verity. These less common deposits will have to compete for a share of the tantalum market with pegmatite resources that require relatively simple processing. The challenges in developing successfully these deposits are favourable permitting, environmental issues, infrastructure requirement, large open pit mineable reserves, simple mineralogy and possibility to produce a concentrate out of the mine with a suitable Ta:Nb ratio.

Avalon Resources is as well exploring some very large deposits namely Separation Rapids and the Thor Lake which are located close from a producing mine called TANCO.

Saudi Arabia:

The British exploration firm **Tertiary Minerals** has been working for some time on its Ghutayyah project which is a 400 million tonne deposit. The mine is scheduled to produce 1.5 million tonnes of tantalum ore per year resulting in 270 tonnes of tantalum concentrate. Production of niobium and zirconium would also be included in the project. The capital cost has been established at \$100 million. Research for financing will start as soon as the project is formally registered with local authorities.

2.4.3 Secondary source

Recycling: The value of a metal is the driving force for its recycling. A significant and growing source of secondary supply is the recycling of tantalum scrap which represents today about 20% of total supply. The recycling ratio tends to increase when the concentrate price goes up and could reach up to 25% in the near future. As a comparison, recycling supply in the consumption of other metals can be up to 50% (i.e. stainless steel scrap for the nickel industry).

Tantalum scrap comes in two forms:

- “Old scrap” that includes metal articles that have been discarded such as tantalum-containing electronics, cemented carbides and super alloys. According to a USGS survey (Larry Cunningham 2001), in a “mature” tantalum market like the United States, old scrap only represented 7% of the domestic supply in the US in 1998. The amount of tantalum recycled from finished electronics components is actually small because facilities and recycling techniques have not yet been developed. During the same year a recycling efficiency of 35% was estimated to have been reached (ratio between recovered metal and theoretically available scrap).
- “New scrap” which is produced during the manufacture of metals and articles (borings, turnings, etc.). The majority of tantalum recycling is done with “new scrap” reclaimed and delivered back to tantalum processors who have the ability to process back the metal as primary material again.

The Defense National Stockpile Center (DNSC) - Defence Logistics Agency (DLA): The DNSC is part of the Defense Logistics Agency of the United States, and sells commodities on the open market. The purpose of establishing this stockpile of strategic and critical materials was to

reduce the US dependence on foreign supply sources during national emergencies. This agency currently stores 47 commodities valued at \$1.7 billion in 41 locations. Tantalum products are part of this stock.

Tantalum minerals were purchased in the 1970's from various countries including Brazil, the former Belgian Congo and Portugal. Other forms of tantalum such as powder, oxide or ingots were bought in the 90's from suppliers like CABOT in the US and other international sources.

For sales from this stockpile, the US law states that competitive sales procedures should be used. So the DNSC accepts bids from domestic or even foreign parties. There are two guiding principles followed by the DNSC which are that "sales should avoid undue disruption of the usual markets of producers, processors and consumers", and also should "protect against avoidable loss" (Cheryl Deister, DNSC, Oct. 2004). The first principle is very important. As shown in Table 6 which illustrates the tantalum inventory of stockpile as of Sept. 30th, 2004, there was about 500 tons of tantalum mineral in stock. This is equivalent to half of the annual production from the largest tantalum miner SOG.

Table 6 - DNSC STOCK – Sept. 30th, 2004

Form	Quantity (lbs Ta/tons Ta)
Minerals (i.e tantalite – Ta ₂ O ₅)	1,118,885 / 508
Metal powder (capacitor grade)	34,607 / 15.7
Metal ingots (vacuum grade)	20,388 / 9.3
Carbide powder	12,158 / 5.5
Oxide	40,865 / 18.5

Data source: DNSC Website – July 2005

The scheduled sales and resulting stock levels of tantalum products for the period of Oct. 2004 to Sept. 2005 is summarized in the following table 7:

Table 7 – DNSC Tantalum stocks and planned sales – 2004

Form	Planned Sales (lbs Ta/tons Ta)	Remaining Stock (lbs Ta/tons Ta)
Minerals (i.e tantalite – Ta ₂ O ₅)	500,000 / 227	618,885/281
Metal powder (capacitor grade)	34,607 / 15.7	0
Metal ingots (vacuum grade)	20,388 / 9.3	0
Carbide powder	4,000 / 1.8	8,158 / 3.7
Oxide	20,000 / 9.1	20,865 / 9.5

Data source: DNSC website – July 2005

Information on quotes offered by potential buyers is not released to the public. There are some pre-negotiated terms, and companies wishing to participate must register in advance. After a sale is agreed to, assuming the bidder was eligible in the first place based on its profile and financial position, only aggregate or provisional contract amounts and a company name will be made public.

It is very interesting to note that, after probably another year, the DLA stock will no longer be part of the tantalum industry supply picture because it is almost depleted. This could put some upward pressure on the concentrate price.

Tin Slag: Tantalum is also available from low and high grade tantalum bearing tin slags, which is a by-product from tin smelting. Tin slag represented about 45 tons in 2004 and it

accounts for only 2% of total supply while in the past it used to be the majority. This business takes place mostly in South East Asia, Brazil and Australia. In both Thailand and Malaysia, tantalum is recovered by many small size companies. The ore type containing tantalum is called struverite and is recovered as a by product of tin during the secondary processing operations. However this source is decreasing due to the scarcity of available material and the rising cost of processing lower grade materials. For low grade tin slags, treatment by pyrometallurgical technique to upgrade the slag to a synthetic concentrate needs to take place. HC Starck in Germany used to specialize in this field. In the past tantalum containing tin slags were a very important source of tantalum supply but this has changed due to structural changes in the tin industry. The current supply comes from accumulated slag stocks.

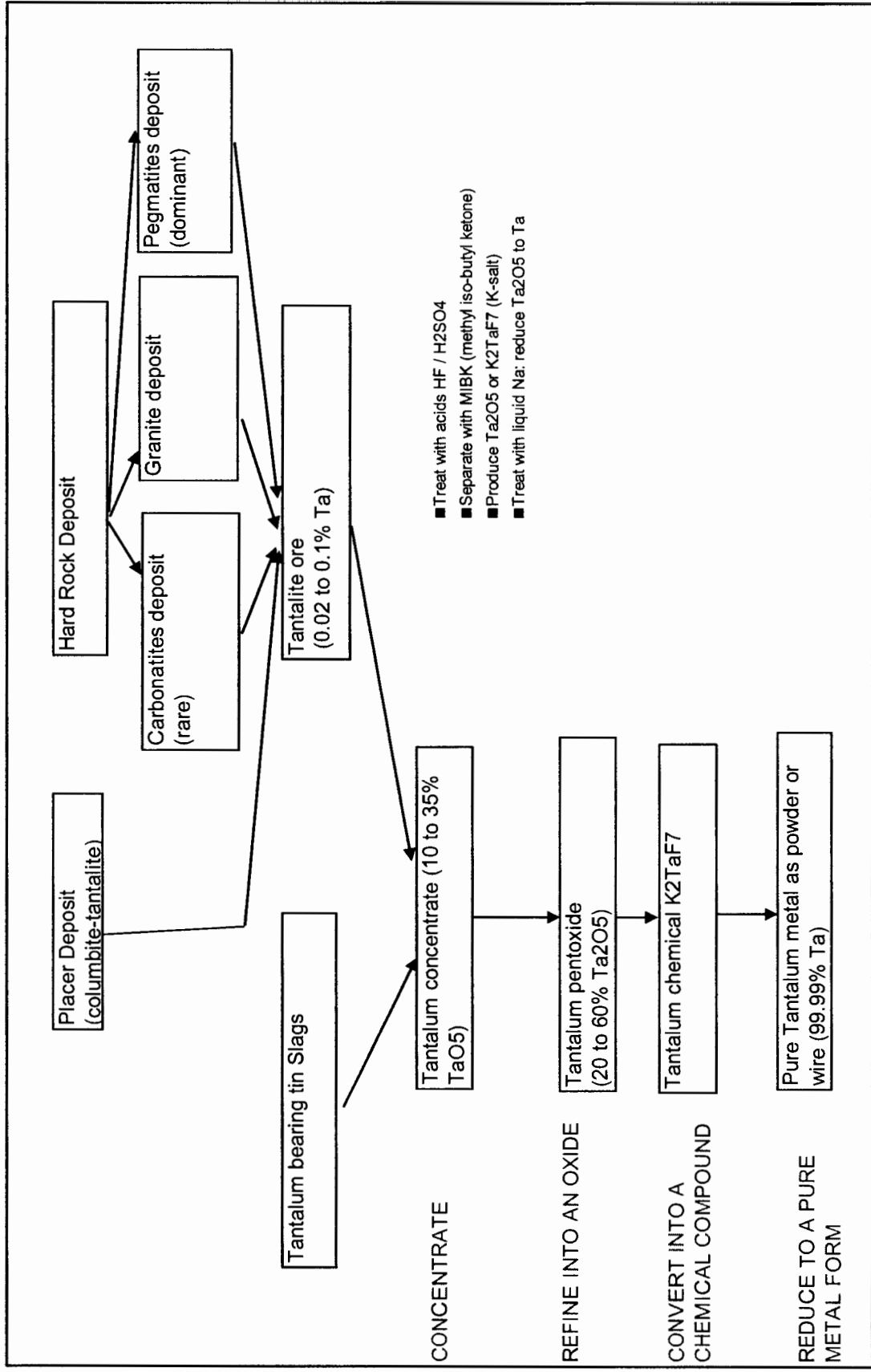
2.5 Processing

Processing tantalum metal is a complex operation (see figure 1). Being a refractory metal, tantalum has a very high melting point of close to 3000°C. Traditional smelting processes used with other metals like nickel, lead or zinc cannot be used in the case of tantalum.

2.5.1 Processing the ore

Most tantalum mining operations used to be small, relatively high cost intermittent operations that depended on the recovery of other metals for economic viability. Since the opening of Sons of Gwalia (SOG) mine, the industry has evolved towards primary tantalum mining. Processing methods used to extract tantalum from alluvial deposits in Africa and from tin slags in South East ASIA are very primitive, worked by hand in open pit mining situations.

Figure 1 - Tantalum production flowchart



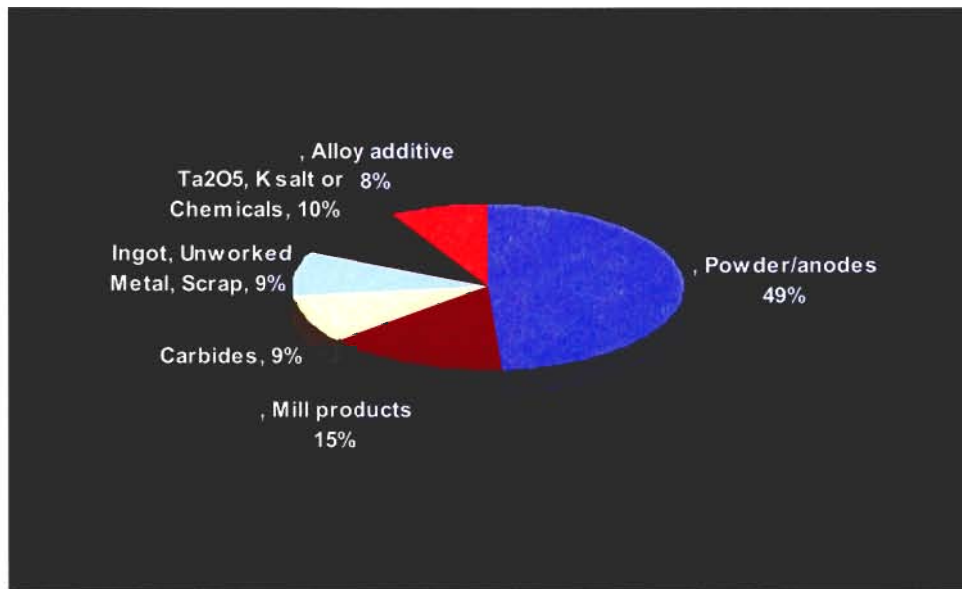
The mining of hard rock is carried out by blasting, transporting, and crushing the ore to free tantalum. The material is then concentrated by various possible wet gravity techniques and finally separated from other associated minerals by gravity, electrostatic and electromagnetic processes.

2.5.2 Transforming ore into metal

This ore has to be treated with strong acids so that tantalum oxide and other components can be extracted from the mineral. Because of its very similar physical attributes to another metal called niobium, tantalum and niobium are very difficult to separate. A chemical operation is necessary to separate the two metals and convert tantalum into a chemical compound more easily reduced to form tantalum metal powder. Tantalite has to be treated with a mixture of hydrofluoric acid and concentrated sulphuric acid in order to dissolve the tantalum oxide or other compounds in the mineral concentrates. The solution is then mixed with methyl isbutyl ketone (MIBK) to effect solvent extraction, and after washing and drying, tantalum oxide can be obtained. Or if potassium hydroxide is added to neutralise the solution the product is K-salt, potassium tantalum fluoride (K_2TaF_7). In order to obtain metal, the tantalum oxide is reduced with molten sodium. This process is difficult and the reagents used have to be carefully kept and used, so they are strictly controlled and environmental regulations are observed.

The reduction process gives birth to two different grades of tantalum powders: a capacitor grade and a metallurgical grade. Because of its better quality, capacitor grade powder is more expensive than metallurgical grade.

Figure 2 - Shipment by tantalum products – 2003



Data source: Tantalum and Niobium International Study Center (TIC) statistics - 2003

Tantalum in powder form represents 49% of total shipments of tantalum products followed by mill products (15%) which are tantalum wire, plate or pipes. Carbides (9%) are tantalum compounds used as composites with other elements in the manufacturing of industrial cutting tools (dies, punches, boring bars, etc). Ingots or unworked metal (9%) are later processed to produce solid pieces such as heat shields, tank linings or exhaust systems. Tantalum K salt or oxide chemical (8%) can be purified and used in glass manufacturing process. Finally about 8% of tantalum in various forms is used as an alloy additive in cobalt-based super alloys or for medical implants.

2.5.3 Possible evolution

The University of Boston supported by Tantalum Australia is working on a new manufacturing process called solid-oxygen-ion-membranes (SOM) which would simplify the process described in the above chart by directly converting tantalum oxide (Ta_2O_5) into a very high purity tantalum powder. This new method of separating metal, by osmosis, is still in an experimental phase.

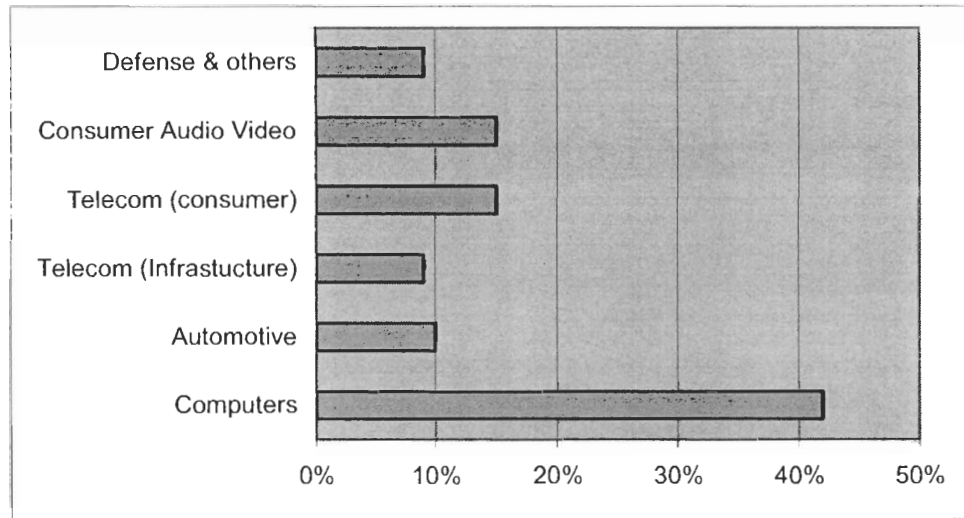
As of today, no player in the tantalum industry is fully vertically integrated from the mine to metal production. Vertical integration will be explored later in this paper to see if this could be of strategic interest to current or prospective industry participants.

2.6 Demand

Demand for tantalum has been growing for the last 20 years at an impressive average rate of 7%pa and at a rate of 11%pa for the last 10 years. However the demand has not been stable and steady. It reached a record level in 2000 followed by a crash in 2001. Overestimation of demand, sharp reduction in capacitor production and high level of stocks have lead to annual consumption growth of 2 to 4% pa, well below historical averages.

Applications in which tantalum containing products are used are summarized in the following chart (figure 3). The computer manufacturing sector dominates with 42% with the shares for other end uses evenly distributed:

Figure 3 – Tantalum applications per end use sectors



Data source: Gartner – SONS OF GWALIA web site - June 2004

Historically the significant activity in the tantalum demand started in the 1950's when the US government decided for strategic reasons to purchase 6800 tons of tantalum in various forms. This event basically set the foundations of the tantalum industry of today by fostering the development of large deposits.

The 1960's saw the emergence of the electronics sector with the manufacturing of tantalum capacitor as the main demand driver. Demand peaked along with prices in 1961 and 1966.

The following decade was characterized by increasing prices, shortage of ores and the first appearance of substitution. During the 1970's an organized tantalum industry was in fact

coming together with increased rivalry between players, threats of substitution in play and increasing uses of tantalum in many sectors which led to stockpile in order to properly address the demand.

After peaking in 1980, the demand-reducing activities were accelerated and in the consumer-electronics sector for instance, aluminium multi layer capacitor took a share of the tantalum capacitor demand. 1982 saw probably the largest stockpile inventories over demand with 5000 tons.

From 1990 to 1998, the demand remained strong with steady and increasing consumption in most years. Thanks to the boom in computers, the 1990's was the golden decade for tantalum demand. In 1991, the largest concentrate supplier SOG entered into long term contracts with the two largest processors CABOT and STARCK and this commercial agreement stabilized the demand.

In 2000, the demand hit an all time high mostly attributable to the technology bubble and levels of market speculation. From 1999 to 2001, there was already a slow down owing to a continued emphasis on miniaturization of electronics components which resulted of course in less needed metal per unit.

In 2005 the overall demand is almost back to the pre-boom levels of 1999. A further analysis of the tantalum demand reveals a complex convergence of trends. In the electronics sector for instance which is the main demand driver, the number of capacitors sold is increasing (+8% in 2004 according to Frost & Sullivan) but their size is decreasing. Furthermore, processors have improved the quality of their tantalum powder. As a result capacitor producers make better use of it and have been able to reduce the consumption of powder per capacitor. Finally there is an alternative for electronics integrators to use other types of capacitors (Al, Nb, etc) in some applications hence affecting again the tantalum demand for tantalum levels.

2.7 Distribution and transportation

Because of the small market size and the large and volatile presence of African supply (369 tons yearly), the tantalum market attracts, from time to time, metal traders seeking profit and short term market opportunities. Indeed a relatively small investment along with a good reading of the market supply and demand can result in substantial profit. In 1999 and 2000, many buyers of tantalum capacitors faced great difficulty in securing supply. Some of them felt that they were victims of exploitative pricing from suppliers. HC Starck, the second largest processor of tantalum in the world, has analysed what happened in a paper published in 2004 (William A. SERJACK, Dr. Hady SEYEDA and Christian G. CYMOREK – Tantalum Availability, HC STARCK, 2004) and came to the following conclusions:

- Tantalum capacitor manufacturers overestimated the demand and produced well above what the market needed.
- Speculators and traders got involved at many levels of the value chain and accelerated the perceived shortage.
- The complexity of the value chain along with the lack of communication between the various industry players limited a quick and appropriate market response.

2.7.1 Transportation

Most commonly tantalum concentrate is transported in metal drums on pallets by sea. When it is of high concentration (>40% Ta₂O₅) and located in remote African locations with no traditional ground links, the product is shipped by air. This shows that for some deposits the access to a sea port, crucial in the economic viability of mining project, is not a necessity for tantalum.

2.7.2 The Radioactive issue

Recent changes to the regulations recommended by the International Atomic Energy Agency (IAEA) have resulted in a lowering of the radioactivity limit in materials transported across the globe as normal goods. There is a very small content of uranium and thorium in tantalum minerals. These elements remain in the concentrate after the initial ore treatment. The industry association TIC has conducted a survey and found that the majority of concentrates produced have radioactivity levels of up to 40Bq/gram. Unfortunately the new regulation has moved the ceiling from 70 down to 10 Bq/gram and possibly less. This implies that many offered concentrates are classified as dangerous goods that carriers refuse to transport. Most concentrates, like the one produced by the market leader SOG, have low radioactivity content but some do need particular packaging and documentation. This is a serious issue that the tantalum industry is presently actively working on and has formed a transportation committee in order to raise the radioactivity level to a more manageable limit for the whole industry.

2.8 Supply/demand balance

2.8.1 World Price of tantalum

Most metals such as lead, zinc or copper are traded on commodity markets like the London Metal Exchange (LME). In the case of tantalum raw material, there is no reference price and materials are simply freely negotiated between two parties. Over the past 30 years, the tantalum market has been marked by long periods of stability, punctuated by very sharp price hikes created by a combination of strong demand and fears about shortage. There are two prices prevailing: a spot price depending upon each new transaction and a long term contract price

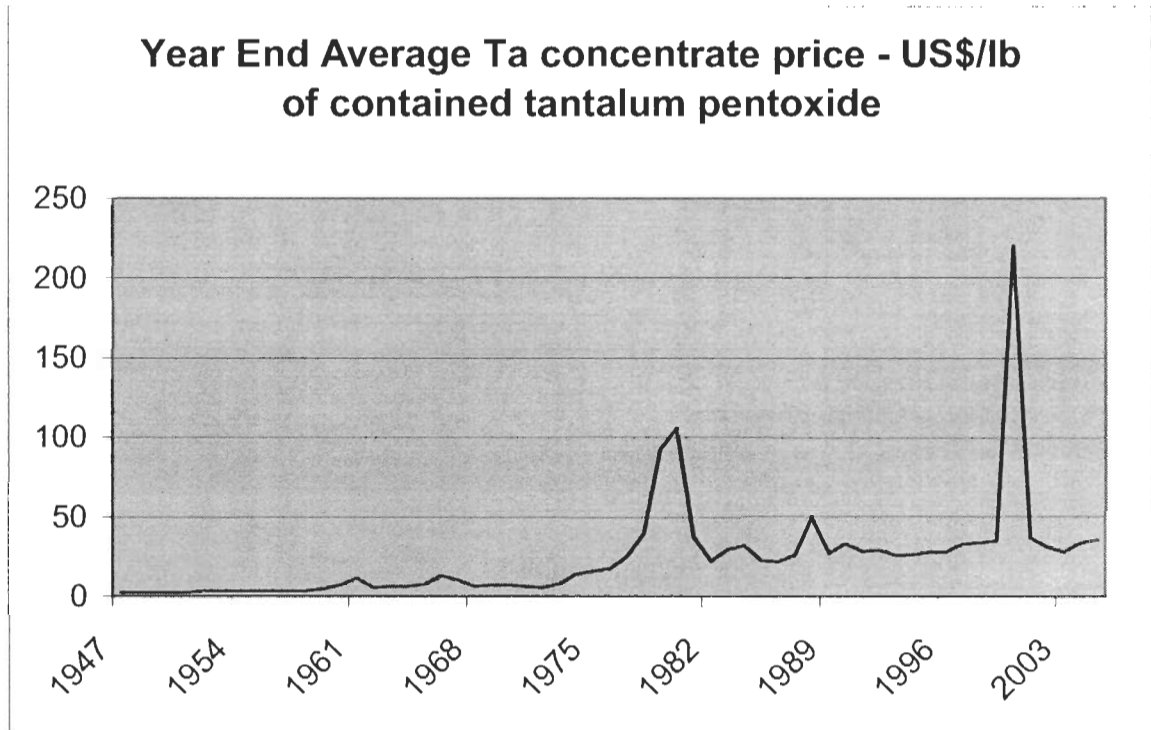
which often includes volume commitments between parties. The following is a current summary of prices for the three main tantalum products in the industry:

- Tantalite or tantalum pentoxide (Ta_2O_5), also called tantalum concentrate. Prices are \$30 to \$40 per lb (or \$14 to \$18 per kilogram) of Ta_2O_5 contained in the concentrate. Concentration of Ta_2O_5 is generally between 10 to 60%.
- Tantalum oxide powder (Ta 99.9% in purity) consumed in electronics capacitors. Prices today are about \$500 per kilogram – Ex Rotterdam warehouse basis (Platts Metal pages June 2005)
- Tantalum metal ingot (Ta 99.99% in purity) for the super alloy industry. After low level of \$200/kg in August 2002, prices have recovered to a level of \$700/kg.

Stability was reinforced when the two largest processors Starck and Cabot signed long term agreement with the leading miner SOG. These arrangements helped to stabilize prices when the consumer electronics and mobile phone sectors went through a tremendous period of growth in 2000. The spot price jumped but it only represented a small share of market transactions.

The only pricing information published is a reference to tantalite mineral concentrates in a UK weekly publication called "Metal Bulletin" (figure 4). Another price indication comes periodically from the US Defence National Stockpile Center (DNSC). This information is available on DNSC website and through press releases.

Figure 4 – Tantalum prices



Data source: Platt's metal week, USBM, Metal Bulletin – Basis 30% Ta₂O₅ CIF – Max U₃O₈ and ThO₂ combined

2.8.2 An unstable balance

The supply demand balance determines the price of any commodity and this applies as well to tantalum. The price of tantalite plays a key role and has a great influence on tantalum powder and tantalum metal prices discussed previously. It is important to point out that the tantalite market leader, SOG, sells the majority of its production to the two largest tantalum processors making the spot price of tantalum concentrate not very representative of the real supply-demand position. Tantalum powder is largely influenced by the demand in the tantalum capacitor industry linked to the growth in electronics. Tantalum metal is greatly dependant upon the super alloys sector for the aeronautic industry but as well on the tool manufacturing industry.

Prices can vary greatly because the market is relatively small with an annual demand of less than 3000 tons worldwide and potential growth increase in derived demand reaching levels of 30-50% yearly.

3 INDUSTRY VALUE CHAIN

As it is summarized on figure 5, the tantalum industry is fairly complex and is comprised of basically 6 segments which are: explorers, miners, processors, producers, integrators and recyclers. Each segment will be described, reviewed and analysed.

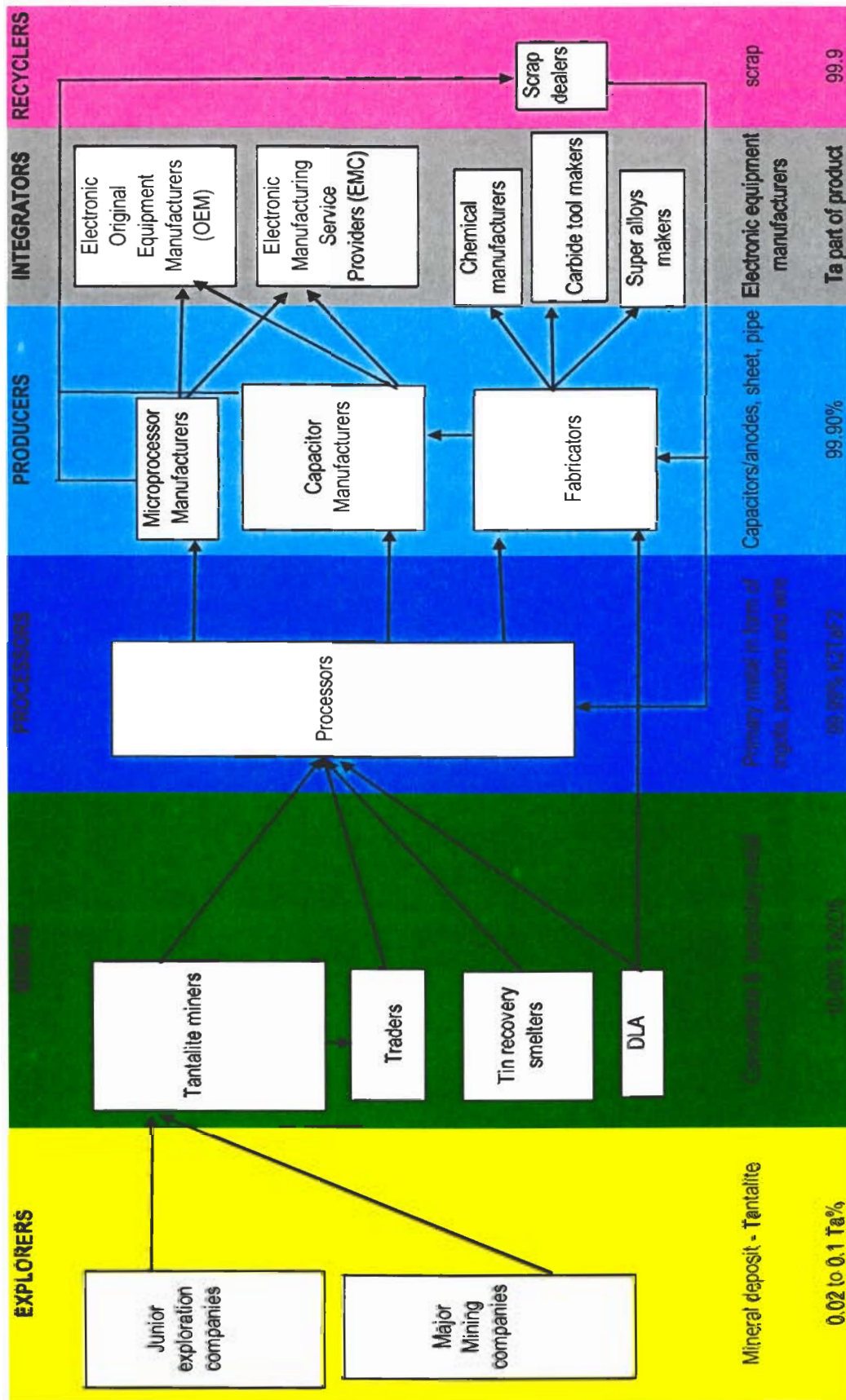
This diagram also summarizes the product or service offered by each of the segment together with the tantalum concentration in the product.

3.1 Explorers

Large mining companies can either manage “in house” the exploration of deposits or acquire projects from junior mining companies and this is an eternal debate in the industry.

The main reason for a major mining company to have an exploration department is to fully take advantage of potential revenues of a mining project without having to pay royalties or share the ownership. The main disadvantage is paying for the cost of a potentially less efficient internal exploration department that may not be able to find successful projects given the natural uncertainties of our mineral soil. It is interesting to notice that none of the major world mining companies (BHP BILLITON, RIO TINTO, CVRD etc.) are directly involved today in the exploration of tantalum.

Figure 5 – Tantalum value chain



Instead, majors typically become involved with many junior exploration companies (BHP for instance has 50 companies in its portfolio) through alliance, joint venture or even as a minority shareholder.

The first segment of the tantalum value chain is structured with the presence of both junior mining companies and major mining companies. Figure 6 summarizes some of the main junior players:

Figure 6 – Junior companies involved in Tantalum exploration

Sons of Gwalia (Au)
Haddington (Au)
Quilos International
Tantalum Australia
Angus & Ross (UK)
Highwood Resources
Tertiary Minerals
Alkane Exploration
Gippsland
Commerce Resources (Can.)
Luan Mining Co. Ltd
Avalon Ventures (CAN)

If present miners doing exploration work are excluded, the significant and active junior mining players are:

- Angus & Ross in England supported by a processor called Cabot,
- Tantalum Australia supported by a capacitor maker from the US called Kemet,
- Gippsland in Australia with their Egyptian deposit,
- Tertiary Minerals in Scandinavia, and

- Commerce Resources based in Vancouver, Canada.

In many cases, junior explorers have little interest in taking an underground deposit to production. They prefer to let majors take care of this task. Juniors usually just raise money through venture exchanges to cover their drilling costs while hoping to make their profit on an increased stock price.

3.2 Miners

There are several groups of players within the “miners” segment. The largest are the primary tantalum miners. They have conducted exploration work either on their own, in joint venture arrangements with a junior exploration companies (“explorers”) or simply have purchased the mineral rights to a deposit from explorers who wanted to sell or did not have the financing to support an extensive feasibility study or a production phase. The main players are summarized in Figure 7:

Figure 7 – List of Tantalum mining companies

Primary miners
 Sons of Gwalia (Au)
 Tanco Cabot (Can.)
 Haddington (Au.)
 Severin Mining
 Midroc (Gov't)
 Ningxia Non-Ferrous Metals (China)
 Nanjing Tantalum (China)
 Metallurg-Nazareno (Brazil)
 Lake Kivu (DRC)
 Nigerian Mining Corp
 Tanco - Cabot (Can)
 Yichun (China)
 Kenticha (Nigeria)
 Momore - Pitinga (Brazil)

The combined and controlled supply from Australia (Greenbushes, Wodgina and Bald Hill), under the Sons of Gwalia (SOG) banner dominates with about a 50% supply share but it is facing some challenges. Its Greenbushes mine which produced about 415 tons of Ta₂O₂ in 2004 is now faced with higher production costs and lower mineral grades from its open pit mine. The company has decided to move towards underground mining which is more costly. Its Wodgina mine is now the largest hard rock tantalum mine in the world with a production of 635 tons but is facing some ore metallurgical issues.

The second group of players are mining companies, mostly in Southeast Asia, that mine and recover tantalum from depleted tin slag. The two most active are Thaisarco in Thailand, interestingly owned by AOL and the Malaysian Smelting Corp. Their market presence has been greatly reduced over the years due to the decreasing availability of tantalum bearing tin slags.

Traders such as Mitsui in Japan or Pacific Ores in Hong Kong have also played also an important role particularly during supply tension. Traders were also very active before the ban on high grade ore from Rwanda or other central African nations. With the current price stability their role has diminished but should not be ignored in case of renewed market tension.

Finally supply from DLA strategic stock is part of the miners segment because they are a significant source of minerals. Although bought some decades ago, the DLA plays a role in the value chain as volumes of tantalum concentrates are regularly auctioned.

3.3 Processors

Worldwide there are nine manufacturers of basic tantalum raw materials which include powder, ingot, primary metal products (inclusive of sputtering targets), alloys, and chemicals. These players are summarized in the following figure 8:

Figure 8 – List of tantalum processors

HC Starck (GER)
Cabot Corp (USA)
Ningxia (CHI.)

Showa Denko (JAP)
VMC (Japan)
Solimansk (Russia)
Mitsui Mining (Japan)
NAC Kazatomprom (KZ)
Silmet (Estonia)

Cabot Corp, HC Starck, and Ningxia dominate the market with around 80% of the total world output. There is some expertise in Eastern Europe but players in Estonia, Kazakhstan or Russia have not developed joint research and business links with western capacitor makers who dominate the purchasing of tantalum raw materials.

In order to better capture the business dynamics within this segment, we will focus on the two main players and their business strategy:

Cabot Corporation: This public company based in Boston, USA, processes 40-50% of the world tantalum raw materials into powder through its “Super Metals” division. Cabot has also partially integrated upstream as it owns 100% the Tanco mine in Manitoba. It was the second

largest shareholder of Sons of Gwalia and recorded an impairment charge of \$11.5 million in Sept 2004 following SOG's move to seek creditor protection in August 2004. Its refining sites are located in the US and in Japan. Cabot is also very active in looking for, investing in and purchasing supply from potential tantalum mining projects or re-opened mines (Mozambique). Cabot has also secured a long term supply contract with Kemet the largest consumer of tantalum powder until the end of 2009. A similar agreement has also been signed between a German capacitor maker EPCOS and CABOT. This company through its vertical integration strategy has probably the strongest raw material position in the industry

H.C. Starck: HC Stark is a German company with manufacturing sites in Germany, the US, Japan and Thailand. The company is wholly owned by Bayer, a large German chemical conglomerate and does not report its financial results. HC Starck processes 20-30% of the world tantalum raw materials. Unlike the market leader Cabot, HC Starck is not interested in upstream or downstream integration but rather concentrates its resources on improving its product line and its processes through cost reduction or technical innovation. The large number of technical papers written by Starck's engineers is a clear illustration of this point. Starck sources most of its raw materials from one supplier, Sons of Gwalia in Western Australia, on the basis of a two year contract which was renewed in Dec. 2004.

Both major players have very different strategies which seem to lead to a reduction in competition within the processors segment.

3.4 Producers

Producers are actual manufacturers of tantalum containing products. They are divided into two main groups which include tantalum capacitor manufacturers, recently joined by microprocessor manufacturers, and fabricators of tantalum metal products such as wire, sheet,

and pipe. Both groups of producers serve different markets with the exception of tantalum wire production which is made by fabricators but used by capacitor makers.

There is about 26 tantalum capacitor manufacturers worldwide but the market in high capacitance capacitors is dominated by the following 8 players (figure 9):

Figure 9 – List of tantalum capacitor manufacturers

Kemet (USA, Mexico & China)
AVX (Czech) / Kyocera (JP)
Vishay (USA)
Epcos (Germany & Portugal)
NEC/Tokin
Hitachi AIC
Matsushita (JAP)
Samsung Electronics

Over the years, these companies have developed expertise, patents or processes which have given them competitive advantages and limited their competition. They have also expanded globally and taken advantage of low cost manufacturing by opening facilities in China (Kemet in Suzhou, AVX in Tianjin and Vishay in Danshui). All of them are very worried about their tantalum powder supply having suffered through shortages in 2000.

The second group of processors are tantalum fabricators, such as Tantalum Inc. in Germany, which produce finished products such as tantalum metal sheets, coils, wires, bars or tubes. These companies are extremely specialized because they need to support their marketing efforts with technical support given the fact that their customers want to use tantalum in very unique applications that emphasize special properties (such as resistance to acid attack, heat resistance, hardness, etc.).

3.5 Integrators

Integrators are companies which assemble or put together the various components containing tantalum that are then marketed to final end users. In electronics they are original equipment manufacturers (OEM) or electronics manufacturing service providers (EMC) such as the world's largest mobile phone subcontractor based in Singapore called Flextronics or well known players like LG, Samsung, Nokia or NEC. A producer of tantalum capacitors like KEMET has about 30 integrator customers.

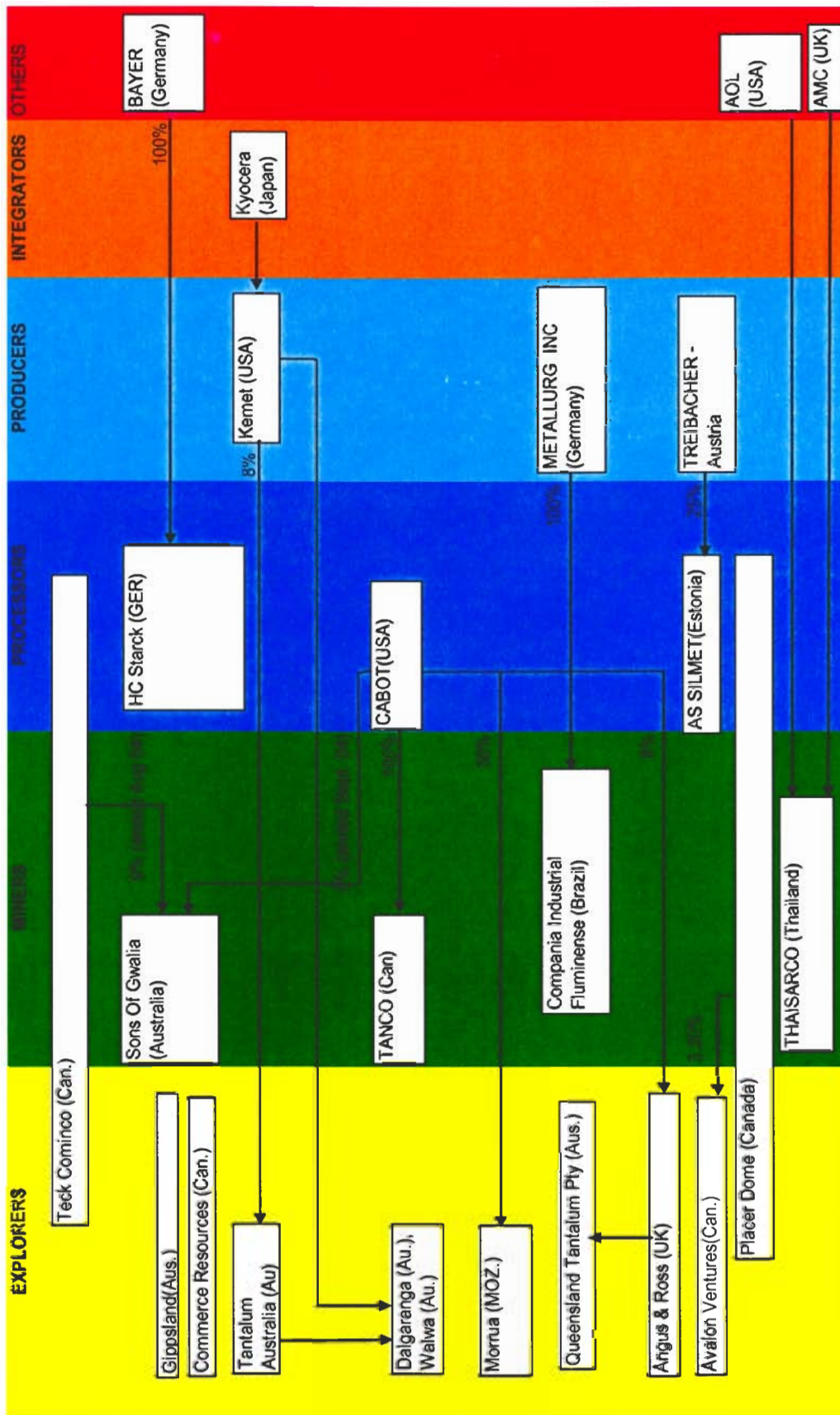
3.6 Recyclers

Recyclers are companies which collect, treat and resell tantalum wastes from producers, integrators or end-users. These wastes are mostly alloy solids, turnings, old crucible, sludge or residues. In the US there are two active players, Exotech and Newlon Metals. They process tantalum-bearing scrap coming mostly from cemented carbides through chemical or zinc processes. Some scraps may come as well from super alloys but the extraction is challenging as there can be more than 25 alloy elements in one turbine for instance. There are 300 companies in USA alone which harvest computer components but the amount of tantalum recovered from obsolete electronics equipment is actually very small. Because of the small size of tantalum capacitors and the difficulty in recovering the tantalum in them, recyclers have not invested but it could represent a major potential for future tantalum recycling.

3.7 Integration along the value chain

The following chart (figure 10) summarizes the locations in various segments and the ownership links between the various players of the tantalum value chain.

Figure 10 – Tantalum value chain integration analysis

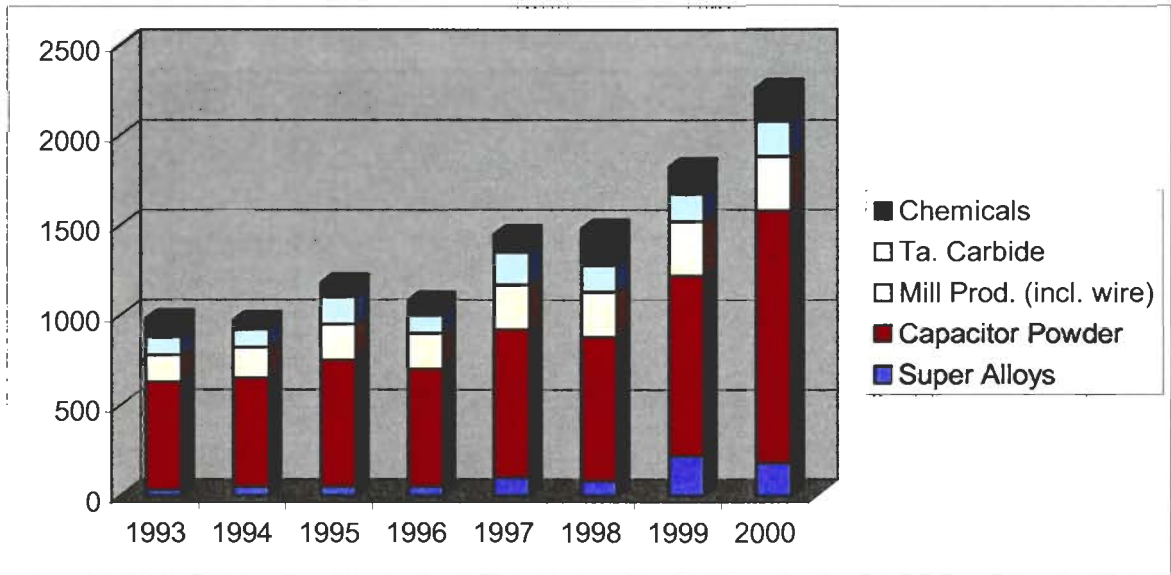


It is interesting to notice that over the years CABOT has invested upstream in adjacent segments such as are explorers and miners. They are very active in working with exploration companies such as Angus & Ross. CABOT owns 100% of Tanco in Manitoba which supplies part of its tantalum raw material. This move seems to have created a barrier to entry as only a few players are in the processor's segment. However this strategy has required increased management force and expertise which can be costly along with increased capital requirements.

4 CONSUMPTION AND TREND BY END USES

Tantalum is used in many industrial applications. The following chart illustrates the consumption by sector over several years. The predominant expansion of the electronics sector is evident and fueled the consumption growth until 2000 while other sectors had moderate growths.

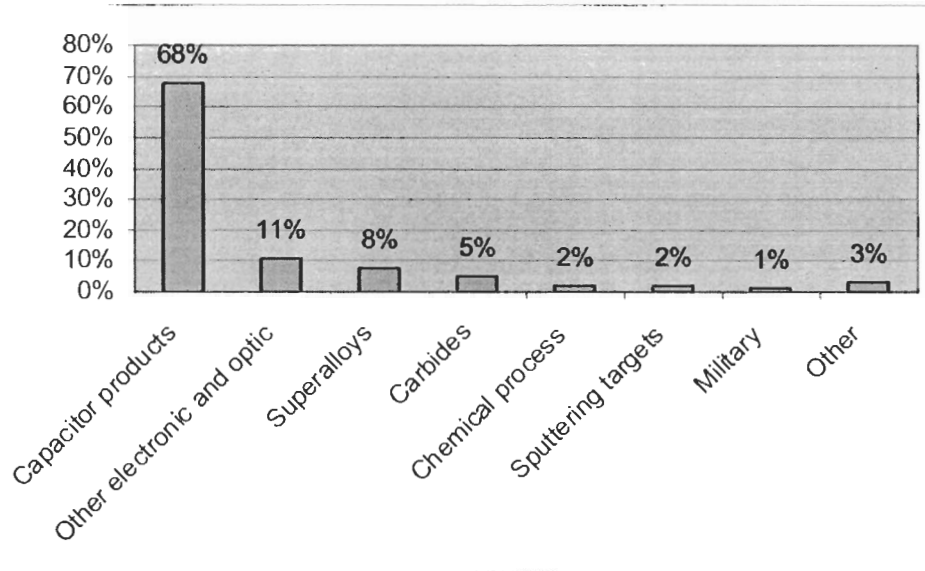
Figure 11 – Tantalum products consumption by sector 1993-2000 (Ta₂O₅ tons)



Data source: Angus & Ross Plc website Oct. 2002

This following graph summarizes the 2004 market share of various sectors. The electronics sector remains very dominant with 68% if tantalum powder and wire supply going into capacitor manufacturing are added. Sputtering targets with 2% are also making their appearance.

Figure 12 – Consumption share by sector – 2004 (volume basis)



Data source: HC Starck – Corporate Website 2005

4.1 Main Applications

4.1.1 Electronics applications

The main tantalum application in electronics is for tantalum capacitors which are produced in the billions every year around the world. Tantalum in a powder form is used in the anode of a solid-state capacitor which is sold to companies producing electronics equipment employing micro circuitry for use in controlling the operation of devices. The largest manufacturers in the US are Kemet, AVX Corporation, Vishay Intertechnology and NEC Tantalum Corp. The largest manufacturers outside of North America include Epcos Kyocera/AVX Corp, and Samsung Electronics.

In terms of general industry dynamics, electronics products are in a long-term growth phase due to the proliferation of mobile phones, personal computers, and consumer electronics.

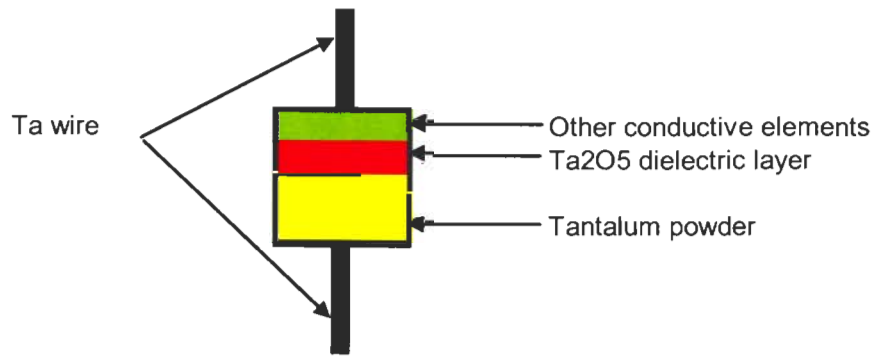
The capacitor industry is characterized mainly by a long term trend toward lower prices for capacitors, lower transportation costs (increasing global competition) and fewer import barriers. Because each device contains many capacitors, the long-term average capacitor unit growth is positive and range on average between 5-10%. The growth of the capacitor industry, however, has been cyclical. This cyclic consumption characteristic is important to keep in mind because it has a great influence on the overall tantalum industry.

Tantalum capacitors are used in integrated circuits to regulate the flow of electricity. Their role is very similar to one of a water reservoir and the distribution of water for a city. They insure continuous and stable outflow of power throughout the entire circuit. Their main advantages versus other capacitors are:

- high temperature stability
- high capacity to volume ratio
- stable capacity over a wide temperature range
- very good frequency

They can be found in applications such as mobile phones, portable computers, LCD monitors, wireless devices, digital cameras, telephone switch boards, computer networks, etc. As an illustration, a notebook mother board (2Ghz) contains 22 tantalum capacitors and a digital camcorder device contains about 13 units and the latest 3G phones have 36 of them. As a general rule each kilogram of powder used in the capacitor manufacturing process requires about 0.2 kilogram of wire. The following drawing (figure 13) shows the location of tantalum powder, oxide and wire in a typical capacitor:

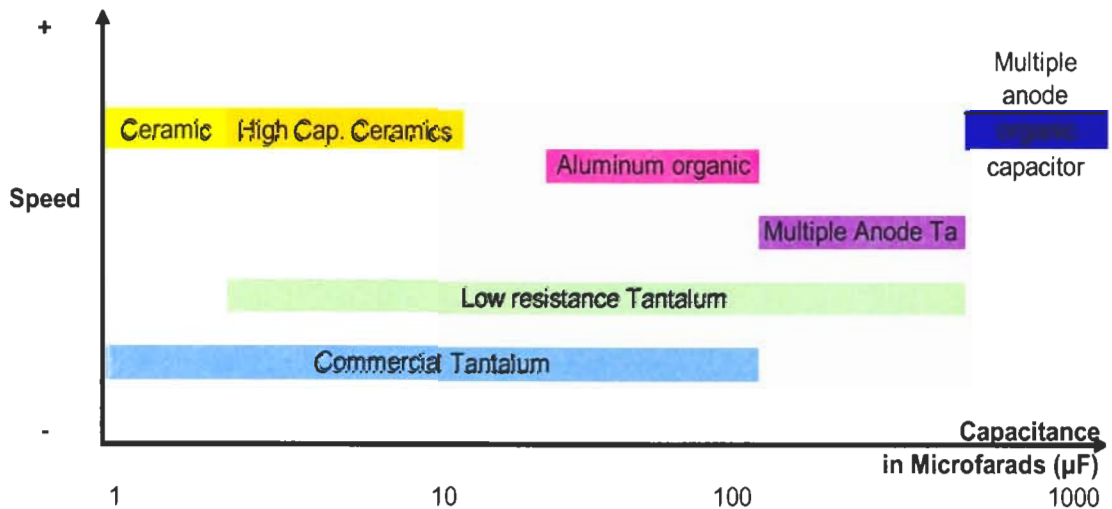
Figure 13 – Schematic diagram of a traditional tantalum capacitor.



Based on Cabot Corporation annual report, 2002

Tantalum capacitors are not the only capacitors that can be used. Generally, ceramic capacitors are more cost-effective at lower capacitance values while tantalum capacitors are more cost-effective at higher capacitance values, and solid aluminum capacitors can be more effective in special applications. This is well captured in the following figure 14:

Figure 14 – Tantalum capacitor market map



Based on Kemet website – information to Investors – 2005

There are other electronics applications using tantalum oxides which include rectifiers (for railway signals), PC memory chips and surface acoustic wave filters. As tantalum nitride resistors, tantalum is also used as a life saving application in igniter chips for car air bags.

4.1.2 Super alloys

Super alloys are simply defined as alloy developed for elevated temperature that encounters severe mechanical stressing. This application is a distant second to electronics with only an 8% share of tantalum consumption. The driving force behind the development of super alloys has been jet engines but also turbines, space vehicles, nuclear reactors, power plants, chemical equipment and other corrosion resistant applications. Because of its unique properties, tantalum plays an important role in nickel-based alloy for jet engines for the aerospace industry. Alloyed at 2-10% with mostly nickel and chromium with a lesser quantity of iron, molybdenum and niobium, this product is used in the manufacturing of turbine blades for engines but as well for land gas turbine in power plants. Alloyed with tungsten (10%) for instance it is also used heavily in flame shields for jet engines to protect fuel lines in the event of fire.

4.1.3 Metal carbides

The third largest proportion of tantalum usage is metal working and other related industries where heat resistance, thermal properties and strength are required. Out of these various applications, the manufacturing of tantalum carbide for the cutting tool industry is predominant. The extreme hardness of this material makes it the hardest man-made substance on the planet. Tantalum carbide is used in the metal industry as an additive for special applications and it is often combined with niobium carbide. It can be found in cutting tools, drill bits, teeth for excavators or for bulldozers used in the mining industry. Cemented carbide which is a pressed

composite of various metal carbide powders uses about 10% of tantalum carbide. They are widely used as cutting tools but also as forming dies.

4.1.4 Sputtering targets

A promising area of increased demand for tantalum is “sputtering” also known as physical vapour deposition (PVD). It is a process which consists of bombarding, with high energy plasma ions, a sputtering target coated with a particular metal such as tantalum or a chemical compound. The impact of the plasma ions cause the deposition of thin tantalum films on whichever objects reside near the target. Growing applications include silicon wafers used in semiconductor devices such as microprocessors and memory chips or even in the application of thin optical coatings onto flat glass or lenses. The potentially largest demand should come from the production of tantalum diffusion barriers in the next generation of integrated circuits. In 2004, for example, CABOT launched a unit dedicated to the manufacture of tantalum sputtering targets, which are used in turn in manufacturing of a wide range of electronics with microprocessors including the booming sector of flat screen TV sets.

4.1.5 Other applications

Tantalum is also used in chemical processes (cladding or coating of vessels), military applications (bullets), textiles (rayon fibres), optical products (coating in lenses), and nuclear applications (heat shields). Tantalum is inert with respect to the human body and can be used in hip and knee replacement systems and in the manufacturing of a variety of surgical instruments and appliances. Tantalum can also find tantalum in the manufacturing of rubber as a catalyst for the synthesis of butadiene. Used as an oxide with another component called Yttrium it provides brighter screen images and reduces patient’s exposure to X-ray radiation in the medical field. It

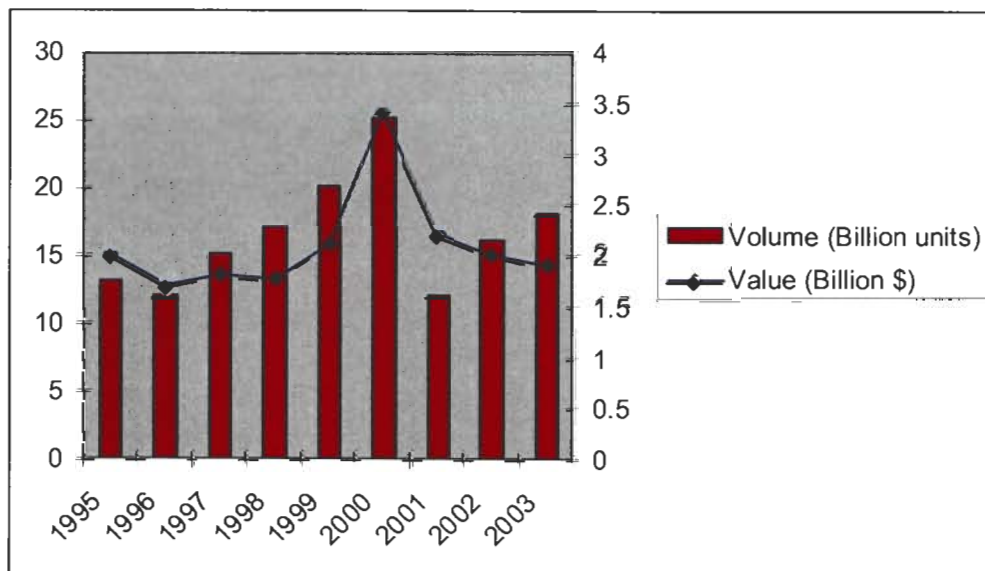
can also be found in camera lenses, X-ray film and ink jet printers. Because of its high price, tantalum is often restricted to small-scale specialized applications within these sectors.

4.2. Growth in Derived Demand

Electronics: Given the electronics sector preponderance to the consumption of tantalum, the following analysis of growth in derived demand focuses on this sector.

In 2004 the global consumption of capacitors (0 to 330 μ F) totalled about 909 billion units and amounted to \$13.6 billion. The growth since 1995 has averaged 11% in volume but only 5% in value. The market in 2004 was divided between aluminium, ceramic and tantalum capacitors with the emergence of other types such as niobium or film capacitors. The following figure 15 illustrates the fact that volumes have recovered but prices for tantalum capacitor per unit have been actually decreasing since 2000:

Figure 15 - Tantalum capacitor consumption



Data source: Kemet website – Information for investors - 2005

We also note the following trend in tantalum capacitor demand:

- Since 2001, consumption of tantalum capacitors is up and has reached a global volume of about 18 billion in 2003. The historical peak was in 2000 with 25 billion capacitors sold.
- The global value is slightly down in 2003 at \$1.9 billion compared to 2002 due to the capacitor size reduction.
- Volumes of ceramic and tantalum capacitors have both recovered but with a market advantage for ceramic capacitors.
- The key demand drivers are computer and telecom production in Asia but it is also interesting to note that automotive and infrastructure demand is set to grow for the future. As an example, cars are now built with a higher number of electronics circuits monitoring the vehicle. Car manufacturers are working to include larger electronics devices such as DVD inboards, satellite radio, night vision, sleep detectors, self parking and many others new features.

It is important to also note that the market is divided between low capacitance capacitors ($<1\mu\text{F}$) which constitute the bulk of consumption with 742 billion units and high capacitance ($>1\mu\text{F}$) with 167 billion units among which tantalum capacitors are mostly found. The study of the $>1\mu\text{F}$ segment provides the most accurate basis on which to forecast the growth in derived demand.

The high capacitance market segment (\$7.07 billion) is dominated by aluminium, tantalum and more recently ceramic capacitors. Out of the \$7.07 billion high capacitance capacitor market about \$4 billion are so called surface mount (chips) capacitors. This market has been growing steadily and in 2004 is shared as shown in the following table 8:

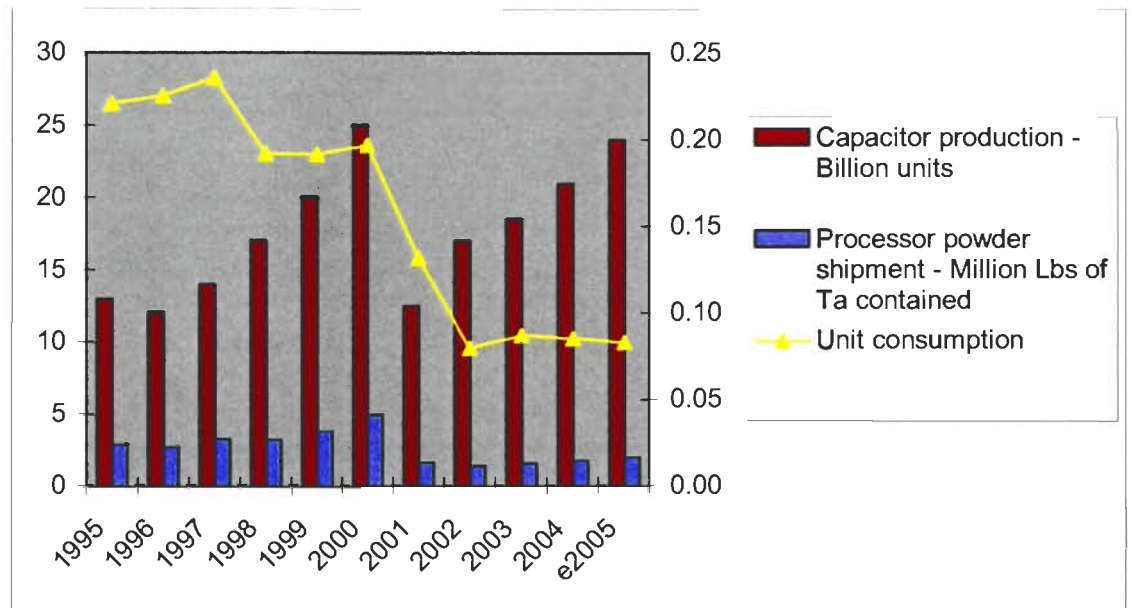
Table 8 – Capacitor market share in the High capacitance market

Type of Capacitors	Market share in value	Market in Billion S	10 year annual Growth	Application
High Cap. Ceramics	45%	1.79	43%	BME MLCC
Tantalum Electrolytic	37%	1.49	5%	Molded & Coated Chip market
Aluminum Electrolytic	14%	0.57	11%	V-Chip/SMD market
Others	4%	0.15	na	EDLC, NbO

Data source: Dennis Zogbi - Paumanok Publications – 2005

In the past decade, innovative ceramic capacitors have basically captured the market growth to reach an equivalent market share with tantalum. In this period, annual growths have been 43% for ceramic and only 5% for tantalum. Combined with a decreased demand and a miniaturization trend in the electronics sector, what was thought to be a future increased demand for smaller components with higher temperature capabilities has not materialized. This following chart (figure 16) illustrates the decreasing trend in tantalum powder consumption per capacitor:

Figure 16 – Tantalum powder consumption in Capacitors



Data source: Statistics from Tantalum and Niobium International Study Center (TIC), Kemet & SOG websites

The future for tantalum consumption in capacitors is not very bright. The following table 9 summarizes the growth of several types of capacitors for the next five years in the high capacitance segment. With the exception of the classic MnO₂ tantalum capacitors, most capacitors should enjoy healthy growth and the segment will overall be the most active product area.

Table 9 – Global surface mount capacitor consumption forecasts 2005-2010 for applications >1 μ F

Type of Capacitor	2005 (market in million)	2010 (market in million)	Annual consumption Growth
MnO ₂ Tantalum	\$1060	\$775	-7%
Ceramic MLC	\$800	\$1200	+9%
Polymer Tantalum	\$430	\$925	+17%
Polymer Aluminum	\$325	\$1025	+25%
NbO Capacitor	\$15	\$145	+60%

Data source: Dennis Zogbi - Paumanok Publications – 2005

Processors are developing better tantalum powder and may be shipping less but are increasing unit prices to capacitor makers. Miners cannot change the nature of their concentrate and are left with lower volumes and stable, even decreasing prices given the possible resulting over supply from processors ordering less powder.

Other sectors: Tantalum consumption in super alloys is expected to grow by about 3% per year according to the TIC. The aeronautics industry is recovering as well as the turbine sector for energy application. Tantalum carbide in metal cutting depends upon the growth of the general economy. We can therefore expect a 2-3% annual growth rate.

With the exception of sputtering targets and the cyclical super alloy industry, in years of high demand, the growth in derived demand for tantalum has slowed significantly in the past few years. Electronics items are becoming commodities. After significant growth in demand of the late 90's in the mobile phone sector (30% - 50% per annum), networks, laptops and wireless

device demand of the late 1990's, devices are now becoming cheaper on a deflated basis. Consumers accept products of lesser quality with lower prices and they change them more often. As a result, resistant tantalum capacitors are not necessarily needed and can be replaced in some cases by cheaper aluminium or ceramic capacitors. The market is satisfied with cheaper electronics devices with reduced capabilities. Tantalum capacitors are becoming smaller due to improvement in technology (powder with higher charge) and consumption of tantalum powder is hence reduced. The perceived shortage of 2000 has also traumatised capacitor makers and is unfortunately leading to what could be described as a tantalum consumption "fatigue".

4.3 Possible Substitutes

Tantalum is not irreplaceable. It is a raw material and it is necessary look at the end uses to find potential threats from substitutes. Substitution generally takes place at a time of high prices and this has happened twice since tantalum oxide prices started to be published.

1979: Substitution came from increased recycling rates and aluminium capacitors (although of lower performance) in electronics.

2000: An all time high peak occurred due to the massive increase in electronics mobile equipment throughout the world. This significant and sudden increase in demand in a relatively restricted market created an apparent shortage which pushed prices to record levels. Ceramic capacitors continued to gain market share and niobium capacitors started to appear.

There are many types of capacitors ranging from multi-layer ceramic capacitors (MLCC), single layer ceramic capacitors (SLCC), aluminum and recently introduced niobium capacitors. Tantalum has only a 4% share of the market and it appears that substitutes are capable of

covering only some parts of the operating range of tantalum capacitors. The year 2000 price peak sparked research initiatives to find a substitution for tantalum capacitors and as a result NEC Corporation introduced in 2001 the first polymer-type niobium capacitor. Niobium is a lot more abundant than tantalum and much lower priced (about 4 times less). Interestingly, the niobium industry has a similar structure to tantalum's industry. 78% of the world's reserves belong to one company in Brazil which produces 80% of the world's production. The main difference is that niobium is mostly consumed in the steel industry. Niobium capacitors offer a higher dielectric constant and can be manufactured on the same production line as tantalum capacitors. A greater current leakage and temperature instability are the two main disadvantages of niobium capacitors. A study by the UK junior mining company Angus & Ross in 2002 revealed that niobium has the potential to replace 10% of the tantalum capacitor market.

5 INDUSTRY ANALYSIS PER SEGMENT

From the previously described tantalum value chain, two segments add the largest value to the chain: miners and processors. Both segments are studied separately in this chapter using Michael Porter's five forces model. Each force below is characterized by several factors. The "+" sign preceding a given factor signifies that this particular factor increases the overall force within the industry analysis making it less attractive for current or potential players. The "-" sign means the opposite. Based on these factors, a general assessment of each force from low to high is given and will characterize the overall attractiveness of the segment. From these two separate analyses, an overall industry attractiveness will be assessed and key success factors will be highlighted.

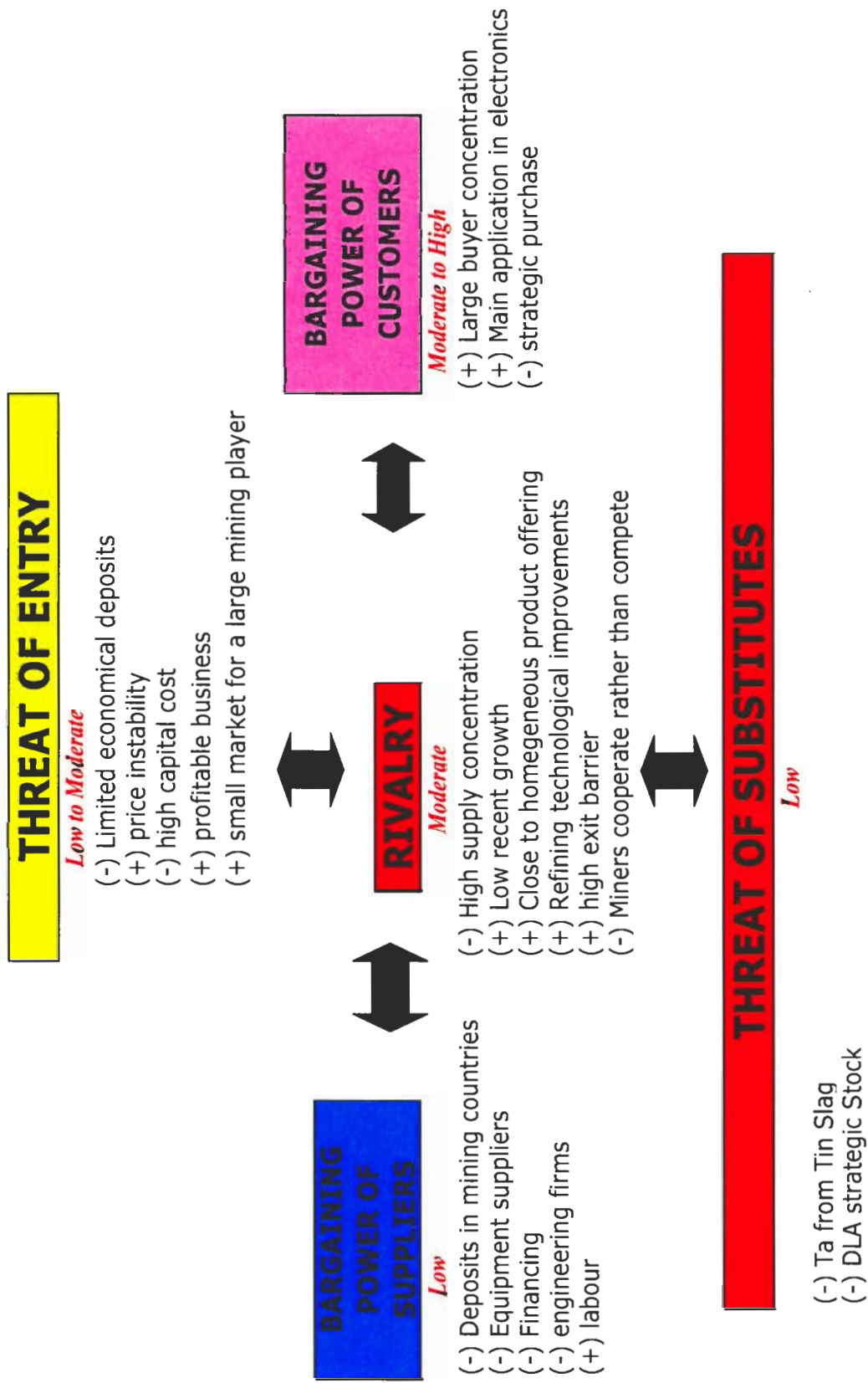
5.1 Miners industry analysis

The following chart (figure 17) summarizes the industry from a tantalum mining company's point of view.

5.1.1 Rivalry among existing miners

As described by M. Porter (1979), rivalry among competitors takes "the form of jockeying for position". We shall now examine the presence of a number of factors:

Figure 17 – Mining industry perspective



High Competitive Concentration: One key characteristic of this industry is the fact that one player Sons of Gwalia (SOG), an Australian company based in Perth, holds a controlling share (about 50%) of the world tantalum concentrate supply with about 725 tons. The second largest player is the Democratic Republic of Congo (RDC), although available output figures may be underestimated. The third player is a German company called Metallurg with a mine in Brazil. Because of the large supply by SOG which sells its tantalum ore through long term contracts (about \$35/lbs), the spot price of \$25/lbs in 2004 has limited influence on the rest of the market.

Low recent growth: Tantalum raw material demand has substantially been reduced in the last five years. In the electronics sector in particular, tantalum demand seems to have reached a plateau. Improvements in manufacturing yield, a lower layer in the capacitor, reduced overall sizes as well as a preference of going to aluminum and ceramic capacitors has reduced demand. This low growth coupled with reduced prices has influenced African suppliers to leave the market which reduces the rivalry among other players during this period.

Homogeneous Product Offering: Tantalum concentrate price is currently at \$30-\$35/lb and is redefined regularly and this is fairly homogeneous. The market is not as fluid as other metals like copper or gold and there are advantages to having better quality which is available from SOG in Australia. Impurities like higher niobium content or uranium presence are considered disadvantages and the market price is then discounted.

Progress in Refining Technology: An exploration company in Western Australia called Tantalum Australia, acquired in 2002 the rights to carry out research and development of a new refining technique with Boston University. If the research is conclusive, the refining yield of tantalite ore into metal could improve from the current 70% to 95%. This would be a major breakthrough and could provide the incentive for the first vertically integrated tantalum producer in Australia.

High Exit Barrier: Processing of tantalum ore into concentrate is a very specialized task and assets related to this process cannot be used for other metal. Rivals keep competing even with low returns as was the case in 2001 when prices hit an all time low in deflated USD.

Cooperation rather than competition: Mining companies generally prefer to cooperate rather than to compete. This can be explained by several reasons which would apply to the tantalum miners:

- Mining companies increasingly develop dominant oligopolistic positions (iron ore, coal, etc) and this is true in the tantalum sector.
- Capital costs are very large and could greatly destabilize a company in a competitive environment.
- A stable long term price allows mining companies to better control their costs.

Looking at the rivalry among existing miners and in view of the above points, we can qualify the rivalry among existing competitors as moderate with potential to be low as soon as growth in the tantalum capacitor market resumes.

5.1.2 Threat of Entry

Limited economical deposits: Tantalum deposits are rare. Economical deposits such as the two owned by SOG (Wodgina and Greenbushes) are fairly unique. Supply from Democratic Republic of Congo, Rwanda, and Uganda with a higher natural grade called Coltan (columbite–tantalite) represents a threat but facts have shown that the influence of these countries is decreasing. There is indeed an increasing pressure from the United Nations and humanitarian organizations not to

purchase tantalum concentrate because the proceeds of this trade are financing destabilizing rebel movements in these countries.

Price instability: Historical price peaks have prompted processors such as HC STARCK to supply the market with tantalum concentrate from their existing stock, in an effort to stabilize price. Hence such market leaders might be tempted in the case of renewed price instability to invest into secured sourcing and to copy the strategy of its main competitor CABOT.

High capital cost: Mining is a capital intensive industry which is a deterrent for potential entry. If one company wants to develop an economically rich deposit, the investment decision must be carefully studied as the capital cost is high. As an example, the greenfield cost of SOG with its two mines was about A\$400-500 million (source: Gary Jones – Teck Cominco – May 2005) and the total concentrate market is close to A\$300 million.

Profitable business: Looking at SOG's financial results, the tantalum concentrate industry is profitable which may be another threat of entry. In 2003, their "Advanced Minerals" division generated sales revenue of A\$205 million and EBIT of A\$57.6 million. Although this includes some tin and lithium production, these co-products of tantalum production are relatively insignificant.

A niche industry: This industry is very small. The estimated annual consumption for 2004 was 2700-3000 tons of tantalum concentrate from various sources and assuming an average selling price of \$30-35/lbs, this gives us a market size of \$180-230 million. A well funded mining group could easily invest and take a large market position.

If we summarize the above factors, the threat of entry into the tantalum raw material industry is low to moderate.

5.1.3 Threat of Substitutes

From a mining company's stand point there is little threat of substitutes from direct demand. As we shall see when we analyze it from a processor's position (the derived demand), the threat is much higher.

Tantalum from Tin Slag: In Thailand and Malaysia, tantalum can also be recovered from low-grade tin slags. In the 90's companies like Thaisarco supplied 10% of world's supply, however the long term production has fallen in South East Asia and Russia due mostly to the decline of offshore tin-dredging operations.

DLA Strategic stock: US strategic stock shall be exhausted in coming years which would decrease the substitution threat to tantalum concentrate.

Even though, there are substitute products that can replace the need of tantalum for processors (the adjacent segment to miners), overall the threat of substitutes to tantalum miners is low and is likely to remain like this for the foreseeable future.

5.1.4 Bargaining Power of Suppliers

Deposits in mining countries: Since the largest deposits of tantalite are located and concentrated in "mining" countries such as Australia, Canada and Brazil, the bargaining power of suppliers within this industry is reduced. In fact, local geologists, engineering firms, financiers, mining

analysts and other services that would be needed to develop your business, can easily be found in these locations.

Equipment – financing – engineering: Suppliers to the mining sector are a myriad of companies or individuals whose industry is a lot less concentrated than the tantalum industry (i.e. equipment suppliers, broker-dealer for financing and engineering firms) giving more power to mining companies.

Labour: The main challenge in these countries, particularly in Australia and Canada, is the availability of labour and its costs. Mining remains a fairly labour intensive industry and the workforce often belongs to strong unions (i.e. Australia, South America). Operations are located in remote areas where the labour availability is limited.

Overall the bargaining power of suppliers is low when demand is strong.

5.1.5 Bargaining Power of Customers

Tantalum concentrate is purchased by tantalum processors who manufacture mostly tantalum powders for the electronics industry as well as ingots and chemicals.

Large Concentration of Buyers: There are eight main consumers of tantalum concentrate in the world but two play by far a leading role: HC Starck and Cabot. Together they purchase SOG's complete production. The combined consumption represents about 70% of the tantalum concentrate supply, resulting in a large concentration of buyers with large power.

Suppliers of tantalum concentrate cannot supply their product to other buyers or industries while Starck and Cabot can offer substitutes like niobium available from their very large product portfolio of specialty metals.

In order to counter balance the situation, tantalum concentrate suppliers like SOG (July 2004 analyst presentation) are increasing their marketing foray into the Chinese market to increase their number of buyers.

Electronics Sector – Main Application: More than half of all tantalum concentrate goes into the manufacturing of tantalum capacitors. These components are devices that regulate the flow of electricity within an integrated circuit. You find them in many applications such as mobile phones, digital cameras, LCD monitors, note books, power supplies and game consoles. Needless to say, this sector has been very dynamic but it makes the tantalum concentrate suppliers quite dependent on one segment of consumption. In 2000 for instance, mobile telephone companies had overly optimistic consumption growth forecasts which prompted capacitor manufacturers to overstock tantalum concentrate and precipitated a large price drop in 2001-2002.

Strategic purchase: Tantalum remains a unique metal which is extremely reliable in many applications. For this reason, tantalum remains a strategic purchase. The two largest consumers have signed long term contracts with the largest supplier and this shows the importance of a secured supply.

The overall bargaining power of customers is moderate.

5.2 Processors industry analysis

We shall now analyze the tantalum industry from the view of a processor. The following chart (figure 18) summarizes the situation.

5.2.1 Rivalry among processors

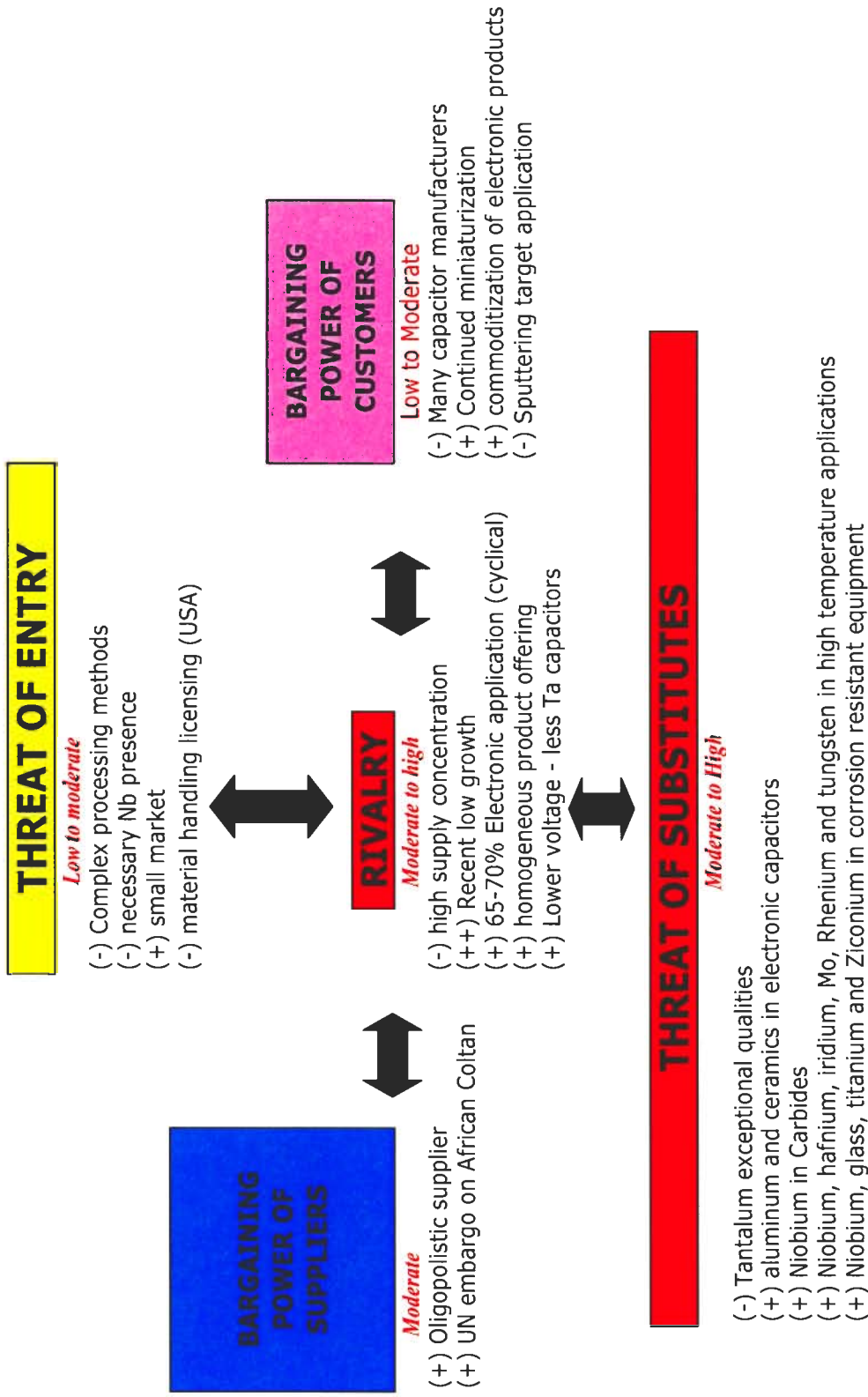
High supply concentration: Cabot and H.C. Starck supply 70-80% of tantalum powder to the electronics industry. This duopoly is further reinforced because the two companies operate on different continents: Cabot in North America and H.C. Starck in Europe. This distinct regional presence reduces rivalry among these processors. Their strategies are also very different and do not conflict. Cabot is always looking at potential vertical integration while H.C. Starck concentrates on improving its product characteristics as well as production capacity.

Low growth: The recent low demand growth started in 2001 is starting to have some effects on processors and the recent corporate announcement (May 2005) of CABOT is proving this fact. Volumes might gradually recover but prices are not and this reinforces strong rivalry among tantalum processors.

Electronics sector: Depending upon the year, 65-70% of tantalum concentrate goes into the electronics either as powder inside a capacitor, as wire as capacitor legs or as metal tray for capacitor manufacturing to avoid contamination. Given the cyclicity of the electronics sector and the over dependence on one sector, the rivalry among processors has increased.

Homogeneous product offering: Probably to a lesser extent than for tantalum concentrate which has a unified world price, the offering of prices of tantalum metal products tends to be homogeneous. Processors have to comply with more or less identical product specifications from capacitor manufacturers or fabricators, reinforcing a relatively homogeneous product offering.

Figure 18 – Processors industry perspective



Lower voltage: There has been a recent trend to producing electronics device with lower power voltages (6-12 V to 4-8V). As a result integrated circuits in these devices need a lower number of capacitors and this increases the rivalry between tantalum processors.

5.2.2 Threat of entry

Complex processing method: As traditional smelting process cannot be used to produce tantalum products, the complexity of the chemical methods used is a definite barrier to entry. Acids used in the process have to be carefully stored, treated and wastes have to be managed according to strict environmental regulations.

Necessary Niobium presence: A presence in the niobium business for a tantalum processor is also a necessity for two reasons. First, niobium is often associated with tantalum in the manufacturing process. As the electronics sector does not support a fully integrated tantalum manufacturing facility, processors must offer both metals for a more effective use of their assets.

Small market: If we assume annual processor shipments of 1500 tons and an average price of \$600/kilogram (powder, metal sheet, wire, etc) the market would be valued at \$900 million which is small. A well financed player could easily take a position increasing the threat of entry to the industry.

Material handling Licensing: As a fully integrated refiner of tantalum ore through finished products, such as Cabot, must procure an annual NRC license which is quite expensive to allow them to handle and process radioactive materials (Thorium and Uranium in particular). Cabot must also dispose of these wastes through licensed processors. All of these licensing processes are very expensive and reduce potential entry by outsiders.

5.2.3 Threat of substitutes

As so often with metals, a threat of substitute arises when prices reach abnormally high levels. As far as the tantalum processors are concerned, the threat of substitutes is a very important concern.

Tantalum exceptional qualities: In some applications tantalum cannot be fully replaced because of its exceptional metal characteristics. If we take the example of tantalum carbide for the tool industry, it is one of the hardest man-made substances. In some critical very hot parts of land gas turbines for emergency power generation, a substitute to tantalum has not yet been found.

Aluminum and Ceramic capacitors: In the largest application for this metal, tantalum capacitors can be replaced by aluminum substitutes. Demand can also be tempered by substitution with cheaper ceramic types whenever possible but with less effective results.

Metal cutting: Niobium, a less expensive minor metal (10 to 25% of Ta price), can also be used when temperature requirements are not as high. Although recently, there has been an increase in demand for tantalum carbides due to their suitability for machining printed circuit boards, the threat remains.

Super Alloys: When these products do not need to withstand too high a temperature, niobium again, hafnium, iridium, molybdenum, rhenium and tungsten can be used.

Chemical: Niobium, glass, platinum, titanium and zirconium can be used as substitutes in chemical and pharmaceutical applications in relation to corrosion-resistant equipment.

The key segment to watch is the electronics sector. A 2000 TIC study estimated that niobium had the potential to eventually replace about 10% of the tantalum capacitor market. As a result the threat of substitution for tantalum is fairly high.

5.2.4 Bargaining power of suppliers

One supplier: Sons of Gwalia (SOG) supplies the large majority of tantalum concentrate to two processors and this gives SOG strong bargaining power. It is almost an oligopoly facing a duopoly with the growing exception of China which has increased its purchase of concentrate from Australia on a spot basis.

UN embargo: The UN embargo covers mainly COLTAN ore. This is a particular kind of Ta-Nb ore from the Congo region. African countries as a whole export around 800,000 to 1 Million lbs of Ta205 in Ta ore on an annual basis-excluding COLTAN.

Overall these two factors moderately increase the bargaining power of suppliers to the tantalum processor industry.

5.2.5 Bargaining powers of customers

Many buyers: There is a broad range of buyers from tantalum capacitors manufacturers to tool makers and medical implant makers. There are 50-100 customers purchasing tantalum from processors on a regular basis. If we take the electronics industry alone there are 26 known capacitor manufacturers throughout the world.

Continued miniaturization: Over the last 3 years, the average size of tantalum capacitors has dropped from about 50 mg/unit to about 30 mg/unit. This is a reflection of the smaller size capacitors in demand in the electronics end markets. The reduction in size is basically due to three reasons: new circuit designs, lower voltages and lower powder requirements. Shipments by

processors according to the Tantalum and Niobium International Study Center (TIC) has dropped from high levels of 2239 tons to 1500 tons mainly attributable to the capacitor applications while the demand for other sectors remains fairly stable in volume.

Table 10 – Tantalum processor shipments (in tons)

Tons	2000	2001	2002	2003
Capacitor powder	1363	750	618	736
Mill products	332	219	241	227
Chemicals	145	172	145	145
Carbides	177	200	141	141
Tantalum ingot	127	141	127	136
Metallurgical powder, Unwrought metal & scrap	95	86	136	127
Total	2239	1568	1408	1512

Data source: Statistics from Tantalum and Niobium International Study Center (TIC) - 2004

Commoditization: There has been a recent trend for lower price electronics that consumers end up keeping for a shorter period of time (e.g. cell phones). As a consequence integrators use less tantalum products as devices do not need to have the greatest technical capabilities.

Sputtering target: This new development and new area of growth is reducing the bargaining power of existing customers. It now represents only 2% of demand but could increase significantly. The market leader CABOT has invested heavily into this new field.

5.3 Overall Assessment of the tantalum industry

Analyzing separately the two key segments of the industry: miners and processors, we can further assess the tantalum industry.

The industry of tantalum mining is small, specialized, and dedicated. It has historically enjoyed healthy consumption growth from high tech sectors, predominantly electronics. Unfortunately the growth in demand for various tantalum products has disappeared in the last few years. One player, SOG, owns two deposits in Western Australia which contain at least 75% of the known global tantalum reserves and supplies close to 50% of world demand for tantalum concentrate. Using Porter's terms, the collective strength of the above 5 forces analysis describes the tantalum miner segment of the industry as rather "soft". Forces rank on average low to moderate. It would appear that there is room for achieving good returns which makes this segment of the industry fairly attractive.

The assessment is different for the tantalum processor segment, which is the second key part of the overall picture. The five forces rank moderate to high on average with particularly strong rivalry among participants and high threat of substitution with other metals.

The industry of tantalum offers interesting opportunities and risks which are summarized in the following figure 19:

Figure 19 – Opportunities and Risks for the tantalum industry

Opportunities	Risks
Historical average high demand growth of 5-8%	Dependent on one large cyclical sector: electronics, others sectors relative low growth
Not a commodity metal, freely negotiated price	Processor segment is controlled by two players (CABOT & STARCK)
US Strategic stocks are almost depleted (end 2006)	Mining segment controlled by one "shaky" company (SONS OF GWALIA)
Supply from tantalum containing tin slags is now negligible	Small market – new entrance could disrupt the balance

Opportunities	Risks
Ethical source of tantalum required for processors (no COLTAN from Congo)	Recent low demand growth 2 to 4%
Very few greenfield projects coming to production in the near future	Ta capacitor market share always under pressure
Bankrupt market leader	Trend towards lower voltage electronics devices
Limited future increase of recycling	Electronics miniaturization
	Radioactive transportation issue
	Steady increase in capacitance value of tantalum powder used
	Tantalum powder – yield improvement in use

5.4 Key Success Factors

Key success factors, or KSF, are “competitive assets or competences that are needed to win in the market place (Aaker 2001).” They are basically the secrets of success in an industry.

When looking at the tantalum concentrates segment in particular, it appears that offering a security of supply to tantalum processors is one of the keys. This has been the strategy of the market leader SOG since 1992 and has been instrumental in helping the company to continue investing in production while operating under present day bankruptcy restructuring.

Another important point is to operate a low cost mining operation while offering the appropriate quality. The market leader, SOG has again been a successful pioneer in this arena.

The ability to discover economically viable tantalite deposits (suitable location and ore grade) throughout the world should not go unnoted. The presence of impurities such as high levels of radioactive elements should be avoided in the ore of new mines. Several companies have specialized in this field and put together teams of competent geologists. Because the odds of finding an attractive tantalite deposit are low, major mining companies outsource this task to junior mining companies and prefer to acquire such deposits after satisfactory due diligence.

For a processor, developing a strong relationship with capacitor manufacturers is also crucial. Cabot Corp. for instance has successfully done so through technical alliances and long term commercial contracts with capacitor manufacturers. Tantalum usage is mostly under threat from indirect substitutes such as ceramic in capacitors or niobium in super alloys. Processors who stay closely in touch with their customers are better positioned for the future market.

Mining companies are not inclined to invest in R&D to develop new applications for the metal they produce. They would prefer to leave this task for downstream companies such as tantalum processors or capacitor manufacturers. A possible key success factor for the future would be to have the ability to accurately forecast consumption at the end users' level (capacitor manufacturers, super alloys producers, etc) in order to monitor production and stocks.

6 RECOMMENDATIONS TO INDUSTRY PARTICIPANTS

In 1999-2000 there were very high hopes for the tantalum industry to develop and flourish. Since then, several years of lower growth have changed the mood in the industry. Mining deposits are well known but there is a lot less attention on the sector in comparison with the hype of 2000. The timing might be right to invest for both current players or newcomers in this industry.

One important aspect of the tantalum industry is that price is freely negotiated between parties. There is no benchmark. In the absence of a market price controlled by a commodity exchange, an effectively managed company has greater opportunity to fashion its own pricing policy. For many metals, the metal exchange paper transactions of a day are equivalent in volume to a year's consumption and pension fund investments play a key role in the trading. The disadvantage of not being in a metals exchange is that financing options with institutions could be limited as the market price of tantalum is difficult to forecast and there are no simple hedging instruments .

Current or potential tantalum industry participants cannot ignore that SOG is today for sale. The courts have assigned UBS Bank responsibility to find a prospective client or an alternative solution to repay all or part of SOG's debts.. SOG's lithium business is inseparable from its lucrative tantalum activity making the split impossible. UBS Investment Banking of Australia is weighing several options including a straight sale of the combined advance minerals division (tantalum together with some lithium and tin production) valued, depending upon various sources, at about \$300 to \$400 million. The appointed administrators are considering a

trade sale but many believe that a float in which creditors would swap debt for securities is another likely option. The administrators are also suing the former auditor, KPMG on grounds that it overlooked accumulation of massive hedging and foreign exchange debts. Tantalum Australia, Cabot and recently Somers-Hayes Group have publicly indicated their interest in SOG's assets.

6.1 To Current Players

Depending where a company is positioned on the value chain, the decision to invest further in tantalum will be positive if the result creates greater sustainable value for the firm (suitable ROI or a minimum opportunity cost). Given their key positions highlighted above in the value chain analysis, miners and processors are the most likely candidates to make some strategic moves because a horizontal or a vertical integration move has some benefits for them. Several scenarios can be considered:

Brownfield project: This involves expanding an existing mine or processing plant. SOG has recently (Nov. 2004) decided to do so although under receivership. The advantages are relatively low capital costs and limited risks as long as the existing deposit and mining infrastructure allow for expansion. The combined expansion capital cost is in the range of \$15-20 million.

Greenfield project: This would mean conducting mine development from a proven underground reserve or building a new chemical facility to produce tantalum powder or metal. The risks are much higher given the high initial capital costs and the unstable nature of a mining deposit but the returns on investments can also be much greater. It is also difficult to exit from the industry if the financial returns and expectations are not met.

Given the recent lower growth in demand, an additional new supply might disrupt the market balance. Such a move would have to be carefully calculated. One exception might be the Chinese market. Several capacitor manufacturers are building new production facilities there to cope with the booming domestic market demand. China could consider investing in and developing a concentrate tantalum production or a processing plant to serve newly developed capacitor producers.

Acquisition: Purchasing an existing player with a track record is probably the most expensive solution. Assuming the acquired company is public, acquisition offers the option to exit more easily than with a greenfield project if the return on investment is not satisfactory. It presents the other advantage of keeping a harmonious supply / demand balance.

Hedging: In general tantalum has gained from the collapse of the tin market which has seen its price gradually decrease from its all time high in the 1980's. If an existing player wanted to enter the tantalum industry, this player could consider tin as a potential hedge. Niobium could also be considered as we saw that processors produce it along with tantalum.

6.2 To Prospective Players

The following are some suggestions to prospective companies interested in entering the tantalum industry.

Greenfield approach: One initial approach, assuming the prospective entrant has an exploration department, is to allocate a tantalum exploration budget. The target would be to locate and acquire the mining rights for a high grade deposit (Ta 0.03% to 0.07%). It would be better to favour pegmatites deposits or even specialty granite resources that require relatively simple processing and have already witnessed other local viable operations . Australia would appear to be the favoured location giving its leadership in the tantalum industry, reliable mining laws, local

government support, and local financial and technical expertise. A second possible approach is to either joint venture with a junior mining company prospecting in tantalum or simply acquire the mining rights from a junior on an existing proven deposit. After tantalum concentrate prices reached a record price in 2000, many projects were announced.

Acquisition approach: Acquiring an existing producer of tantalum concentrate is another possibility. The most obvious solution would be to purchase the tantalum assets of Sons of Gwalia, referred to as the Advance Minerals division. Thanks to its low cost and suitable grade, SOG has progressively increased its grip on the world supply from 10% in 1992 to 50-60% in more recent years. However, increasing costs and decreasing ore grades could see SOG's influence decrease over the next five years.

An acquisition might also make sense if the prospective buyer is a mining company very dependent upon the steel industry. Tantalum is an exception and more in sync with the electronics industry so it could provide a nice counter cycle and complementary activity.

Recycling approach: As tantalum usage is gradually increasing, the recycling rate is also increasing. Entering the tantalum industry via the recycling route could also be a considered alternative. We have seen that tantalum is recycled from carbide or super alloys but a large amount of tantalum is used in electronics where today very little is recovered. This scrap could be a very profitable new source as long as the process to recover the tantalum is available, along with government policies and industry guidelines to recycle the growing number of abandoned computers.

6.3 To Suitable Candidates

This section, profiles companies which could best utilize specific types of investment in the industry

A mining company: Over the next few years, assuming that demand does not collapse, the tantalum market will require fresh supplies of tantalum raw material. Mining companies are best positioned to fill this need because of limited supply from other sources (recycling, DLA and tin slags). As described above, several investment approaches are possible but the development of a new mine or the acquisition of an existing one in Western Australia seem most logical. The region possesses local expertise in tantalum and is perfectly located to supply the coming increasing needs of newly built capacitor manufacturers in China. A company like Teck Cominco or possibly Cabot Corp., although the latest has a limited expertise in mining, would appear to be the right candidates. The involvement of a major player from the mining sector, able to introduce price and supply stability, would surely reassure tantalum consumers.

A minor metal player: Metallurgical companies already in the business of producing niche metals like niobium, gallium or indium could be a very good strategic fit. They understand the commercial and manufacturing specificities of these minor metals which are sometimes obtained as a co-product with other metals or a by-product of other metals. In the case of niobium there is an interesting overlap in its usage in capacitors as well as in super alloys. Together these two sectors represent 80% of tantalum applications. Niobium is also found as a mineral together with tantalum. A niobium player like Companhia Brasileira de Metalurgia e Mineracao (CBMM) in Brazil could be an interesting candidate. Investing in a process to extract tantalum from its existing niobium manufacturing facility in Brazil could provide them a position in the tantalum market. Teck Cominco is also well positioned in the industry of minor metals with its production of germanium and indium.

A tantalum processor: Processing tantalum concentrate into powder is today a complicated step and probably one of the value chain's bottlenecks. Additional investment in process innovation by a tantalum processor like HC Starck, Cabot or even Ningxia could reduce production costs and re-position tantalum as a more affordable product.

APPENDIX

Main websites accessed for this project

Angus & Ross plc	www.angusandross.com
Avalon Ventures Ltd	www.avalonventures.com
AVX Corporation	www.avxcorp.com
British Columbia Geological Survey	www.em.gov.bc.ca/mining/geolsurv/
Cabot Corporation	w1.cabot-corp.com
Central African Mining and Exploration Co.	www.camec-plc.com
Commerce Resources Corp.	www.commerceresources.com
Dpt of Ind. and Res., Western Aus.	www.doir.wa.gov.au
Gippsland Limited	www.gippslandltd.com.au
Haddington Resources Limited	www.haddington.com.au
H. C. Starck	www.hcstarck.com
Kemet Corporation	www.kemet.com
MBendi	www.mbendi.co.za
Metallurg	www.metallurg.com
Minesite.com	www.minesite.com
Ningxia Non-ferrous Metals Smeltery	www.nniec.com
Paranapanema SA	www.mamore.net
Sons of Gwalia Ltd	www.sog.com.au
Tantalum Australia NL	www.tantalumaustralia.com
Tantalum–Niobium International Study Cent.	www.tanb.org
Teck Cominco	www.teckcominco.com
Tertiary Minerals plc	www.tertiaryminerals.com
U. S. Geological Survey Mineral Inf.	http://minerals.usgs.gov/minerals/pubs/country
Vishay Intertechnology	www.vishay.com

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