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POTENTIAL ECONOMIC IMPACT  
ON THE ALUMINA INDUSTRY FROM ALUNITE

by

George Joe Hartman

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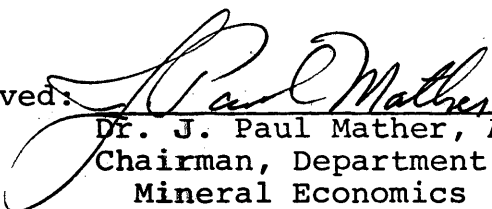
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A Thesis submitted to the Faculty and the Board of Trustees of the Colorado School of Mines in partial fulfillment of the requirements for the degree of Master of Science in Mineral Economics.

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ABSTRACT

This thesis briefly reviews attempts to produce alumina from non-bauxitic sources, other than alunite, pointing out their particular economic shortcomings.

It then inspects those economic factors believed to be most salient to the success or failure of the proposed Alumet process including ore reserves, technical feasibility of processing, return on investment, demand for products, and the overall economic potential.

Finally, after inspecting these factors in detail, the study predicts that a decision will be made in the near future to build a commercial processing facility for utilization of alunite reserves.

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CHAPTER 1. INTRODUCTION

World production of aluminum amounts to about 14 million metric tons per year (Cohen, 1976). The current process of commercially producing aluminum begins with the extraction of alumina from bauxite or laterite ores, using the Bayer caustic leach extraction process developed approximately one hundred years ago. Bauxite is a hydrated alumina ( $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$ ) with silica, clay, and other various impurities. Laterite is a more general term for red rocks that contain hydroxides of aluminum.

The Bayer extraction plant product--aluminum oxide better known as alumina--serves as the raw material used in the Hall electrolysis pot line which reduces the aluminum oxide to aluminum metal. The consumption of bauxites and laterites amounted to 1975 to approximately 100 million tons per year (Cohen, 1976)

At the rate of consumption of at least 100 million tons per year and considering the rate of growth in consumption that aluminum has enjoyed in the past thirty years, world reserves of bauxite and laterite cannot supply the industry for the long run future.

In addition to the fact of decreasing world reserves of bauxite, most of these reserves are located in developing nations. The probability of the developing nations restricting export shipments of raw materials in the future is a very real one and poses a potential threat to users.

With these facts in mind, Earth Sciences, Inc. (ESI) commenced in the mid-1960's, its investigations into domestic alternates for foreign bauxite. Investigations of many materials other than alunite were carried on. Although chemical processing technology could extract alumina from all of these alternative materials, economics were not favorable. In 1969 the company started to investigate the mineral "alunite". The fact that alunite is being processed into alumina in Russia was encouraging.

The Alumet Company, a partnership of National Steel Corporation, The Southwire Company, and Earth Sciences, Inc., was formed in 1970 with the final objective of producing alumina from alunite on a commercial scale, competitive with the conventional bauxite process. The commercial scale operation may be the first such enterprise of this type in the Western Hemisphere.

Sulfuric acid and sulfate of potash are co-products of this process. The alumina production level will be set at 500,000 tons per year.

If successful, the project will provide a reliable, captive, and domestic source of raw material for the production of aluminum metal.

The commercial decision will involve, but not be limited to, economic return on investment, technical feasibility, and business strategy involving, among other things, vertical integration. This thesis reviews some of the aspects that will influence the final commercial decision and attempts to predict that decision.

#### A Summary of Non-Bauxitic Aluminum Production Processes

Methods of producing aluminum from non-bauxitic sources have been examined during most of the industrial life of this metal. Between the period of the First and Second World War, it became evident that aluminum metal would ultimately become a world-wide demand commodity with a variety of uses. It was also apparent that only one mineral was used as a raw material for this growing international industry. These two considerations, combined with lack of bauxite reserves in many of the industrialized nations, particularly the United States, sparked a keen interest in the possibility of producing aluminum from non-bauxitic aluminum bearing sources.

This interest has continued from time to time with increased periods of interest due to significant economic changes and/or political occurrences. A list of these projects is included in the first portion of this thesis as a means of giving the reader some indication of the quantity of activity that has preceded today's quest of finding an economic and technologically feasible alternative non-bauxite source of commercial alumina. This quest has not been a simple one by any means and certainly not an inexpensive task. But as with the fabled search for the Seven Cities of Gold, if once found, the economic potential of the worldwide market for aluminum more than justifies the financial risk of tax deductible research.

Alumina from Leucite (Blanc, 1931)

Leucite ( $K_2OAl_2O_4SiO_2$ ), which is quite abundant in central Italy, was first seriously researched as a source of aluminum in the 1930's. The Italian process included leaching the ore with hydrochloric, nitric, or sulfuric acid to dissolve the values of alumina and potash. This process enjoyed a certain amount of success during World War II but the plant was destroyed by Allied aircraft and was not considered economically justifiable to rebuild after the war due to competition of available and ample bauxite supplies. No attempt to reactivate it is known to exist

now, perhaps due to the limited potential of suitable leucite reserves throughout the world.

Kalunite Process (Fleisher, 1944)

Study on this process was done primarily in the United States and began officially in 1929. Laboratory and pilot plant testing on this process has proven the technological feasibility of it, but, as is the case with many metallurgical processes, the economic feasibility of the project is as critical as the technical aspect and this process could not compete with bauxite on a cost-per-ton aluminum basis.

During World War II further research was continued to obtain an alternate aluminum raw material source in the event our bauxite sources were made unavailable by hostile action. During the war, aluminum metal was actually produced from kalunite alumina but not in an industrially significant quantity and not at a competitive price.

The process again used an acid leach, employing pressure autoclaves for precipitation and a number of purification steps. The combination of many unit operations and substantial reagent and operational costs proved this process commercially non-viable if bauxite was available at reasonable world prices.

The two processes thus far mentioned received much attention after World War I and during World War II while hostility threatened the availability of bauxite supplies. The main emphasis then was not on the possibility of producing aluminum economically but merely producing aluminum to support the war effort if bauxite was not available. With the end of the war, bauxite became available at increasingly larger supplies due to world-wide exploration. With the abundance of accessible high grade bauxite, little or no research was done on non-bauxitic production of alumina.

About 1970 it was again realized that a variety of pressures, economic as well as political (not the least of which was the threatened cartel action by the International Bauxite Association[IBA]), were continually pushing the world aluminum industry to increased interest in producing alumina from sources other than bauxite. These more modern process approaches include the Toth, H-Plus, and various alunite processes. The major difference in the modern research development approach, as compared with the war era development, is the strict attention to the comparative economic considerations in relation to the conventional costs.

#### Toth Process

Applied Aluminum Research Corporation (AARP) is currently developing the Toth process named after its developer, Charles

Toth. Perhaps one of the most radical approaches to the aluminum industry's quest of producing metal from non-bauxite sources, this process, if successful, would eliminate both the conventional Bayer extraction plant and the Hall electrolytic reduction pot line that is used to make commercial aluminum now (Chemical and Engineering News, 1973).

Initial treatment consists of chlorination to form aluminum chloride. The aluminum chloride is then reduced to aluminum metal using manganese metal. The resulting manganese chloride is recycled back to the initial pyrometallurgical step that again produces aluminum chloride and liquid manganese to be used again in the aluminum reduction phase. A simplified flow diagram is found in Figure 1 (Engineering and Mining Journal, 1973).

Co-products can be produced, depending on the original feed used. The production of the co-products such as titanium tetrachloride further improves the overall economic position of the process; however, reactive iron impurities in the feed stock result in high reagent cost from iron chloride formation that must be eliminated in the initial step.

The main difficulty of the Toth process stems from corrosion of the process equipment. Chlorine and chlorides are some of the most corrosive agents known to man. Materials of construction do exist that can withstand the chemical attack, but the cost of these materials and inflated

## TOTH ALUMINUM PROCESS

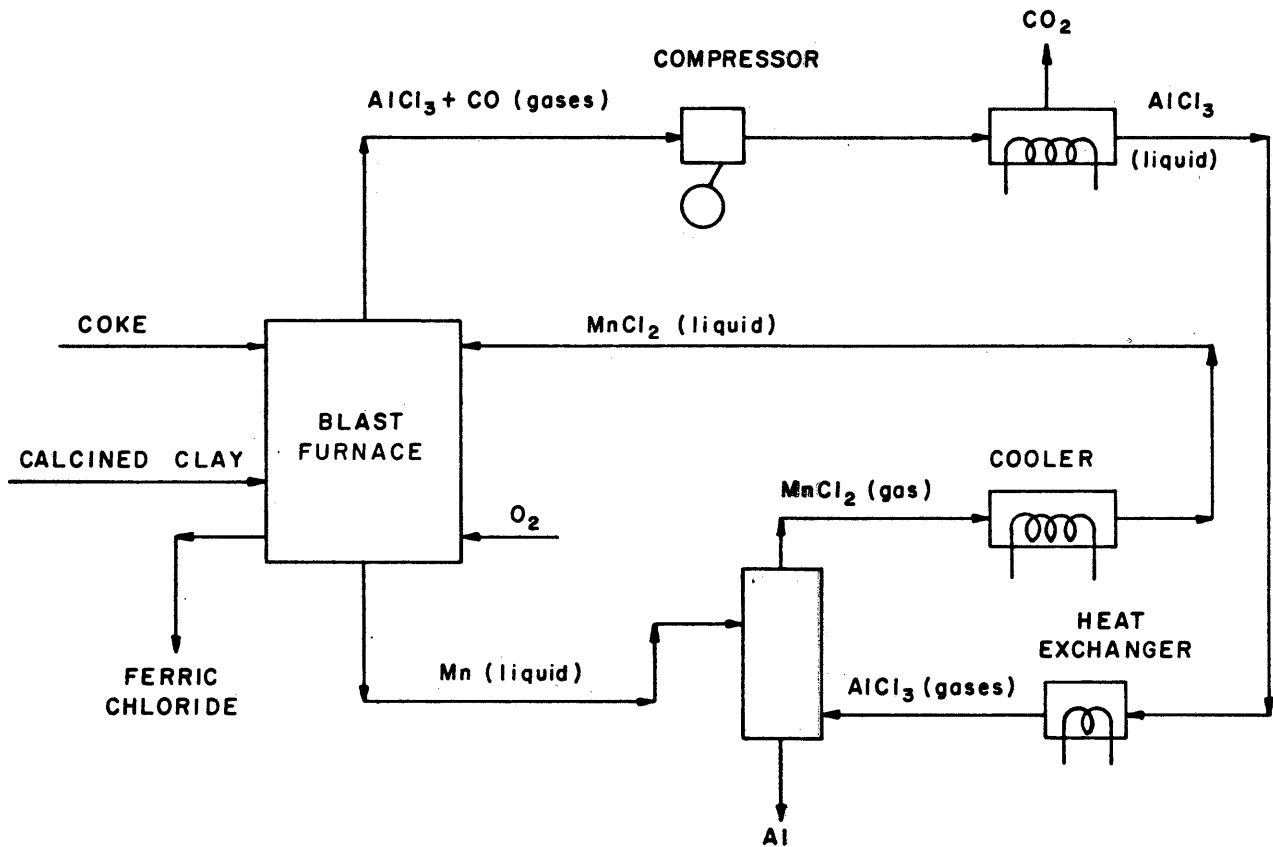


Figure 1 - Toth Aluminum Process Flow Sheet

fabrication expenses escalate the capital expenditure of large integrated commercial plants. The continued contact of the chlorines on the equipment increases the risk of continuous high maintenance costs and replacement expenditure.

The combination of reagent costs because of excessive production of iron chloride and expensive process equipment and maintenance charges, increases the difficulty of evaluating the overall economic picture without first building a plant and operating it for many years. With this in mind, laboratory and pilot plant testing continues to reduce the corrosion problem and improves the probability of more accurately estimating the competitive foundation of this process, as compared with the conventional process.

#### Anorthosite (Peters, 1974)

Aluminum Company of America (Alcoa), the oldest and largest aluminum company in America, puts its major interest in the mineral anorthosite as a substitute to bauxite. Anorthosite is believed to be this nation's largest domestic aluminum resource. Alcoa purchased a huge Wyoming deposit containing about 27 percent alumina in 1972 and has been researching a process to produce alumina in its lab and pilot plant in St. Louis ever since. This deposit could contain alumina equal to one-third the alumina content of the world's known bauxite reserves.

The process consists of sintering the anorthosite with limestone and soda ash. The sintered product is leached and then desilicated, using pressurized autoclaves and additional lime. After desilication the aluminum-bearing solution is carbonated, seeded, and allowed to precipitate to yield the trihydrate of aluminum, which is further calcined to produce the final product for reduction - alumina. For further understanding of this process, refer to Figure 2.

The major problem with this process is a cement-like gel that forms during processing and is extremely difficult to deal with. It also involves many unit operations which produce only alumina and no co-products to help defray processing costs. Only 79 percent of the alumina contained in the original ore is extracted, which is further detrimental to the overall economic position of the process.

#### H-Plus Process

Pechiney Ugine Kuhlmann and Alcan Aluminum Ltd. are jointly developing a process using sulfuric and hydrochloric acids for extracting alumina from non-bauxite raw materials (Engineering and Mining Journal, 1975) The two main ores under consideration are clays and shales.

In this process sulfuric acid contacts the ore first to dissolve the aluminum as a sulfate. The aluminum is then converted to the chloride with the use of hydrochloric

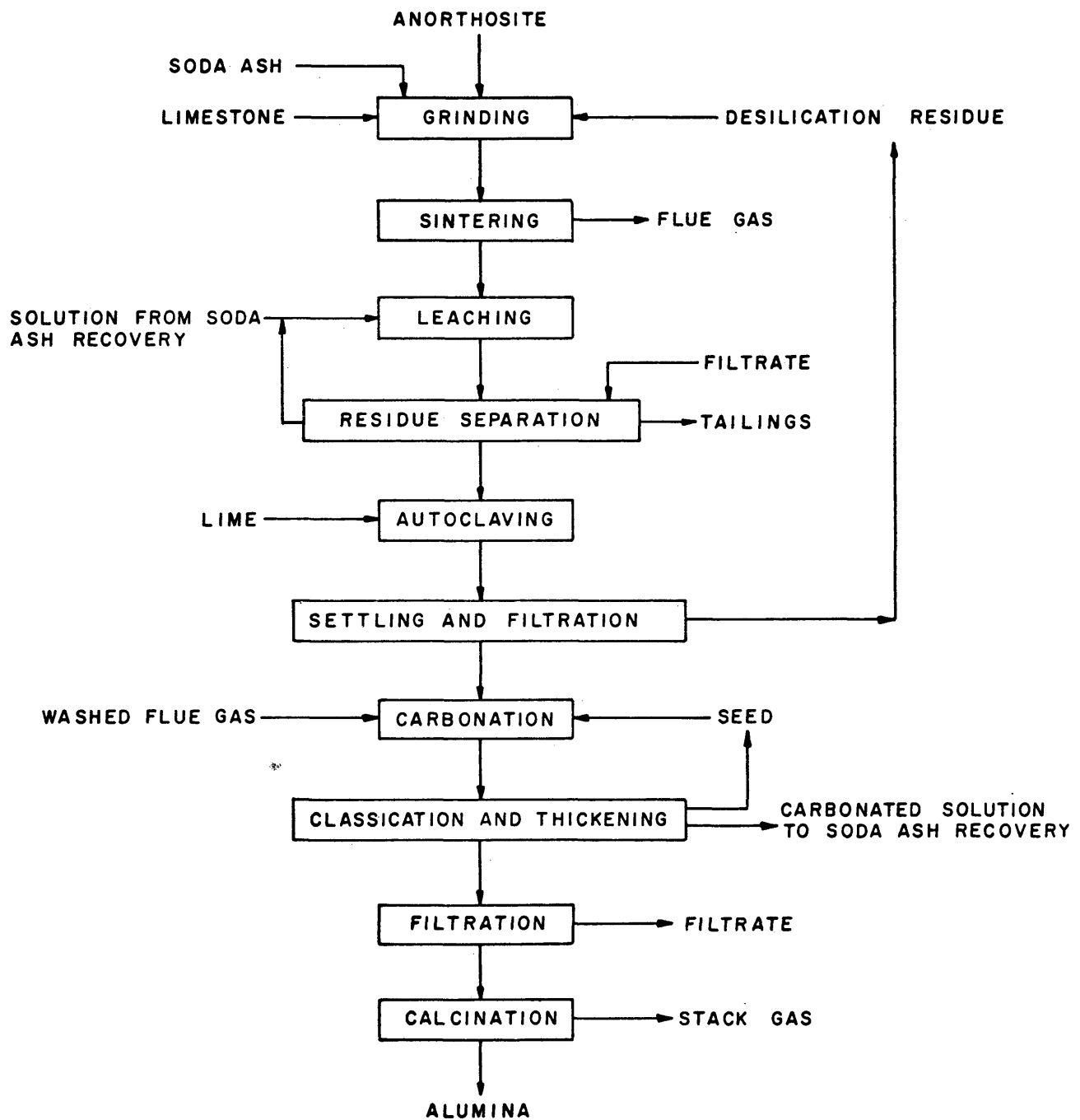


Figure 2 - Anorthosite process flow sheet (Peters, 1975)

acid and hydrochloric gas. This treatment is very similar to the Italian leucite process. After the conversion the material is crystallized as a hexahydrated aluminum chloride. The aluminum chloride is then calcined to the final product, aluminum oxide. The aluminum oxide can then be reduced to aluminum metal using the conventional Hall reduction process.

The H-Plus process of producing alumina requires nine unit process steps which include various purification schemes and pyrometallurgical technology.

Economic considerations include a higher material handling cost compared to the conventional alumina producing methods, due to the reduced grade of the feed (Chemical and Engineering News, 1975). This aspect is true in all the alternative non-bauxitic processes. Energy consumption for the H-Plus or PUK process, as it is also known, is also greater due to the high temperature required for the pyrolysis of the crystals during various steps of the process.

#### Alumina from Alunite

Three principle projects using alunite as a feed stock exist today: Mexican U.G. Process, Russian Alunite Process, and, of course, The Alumet Process.

Mexican U.G. Process. This process was developed by the University of Guanajuato under the direction of Wenceslao Lopez (Parkinson, 1971). The first plant being built at

Salamanca is expected to cost \$800,000 with a feed rate of only about 33,000 short tons per year. The main products will be ammonium sulfate, potassium sulfate, and alumina (see Figure 3). The alumina produced by this plant will be used for other purposes than aluminum metal raw material; therefore, this process will pose no threat to bauxite aluminum production. The total tonnage produced per year is also insignificant as compared with the world consumption of alumina.

Russian Alunite Process. The Soviet Union has been operating a commercial scale alunite processing facility at Kirovabad, near the Caspian sea for at least the last 10 years (Parkinson, 1974). The Russian process does commercially produce alumina that is reduced to aluminum metal. This process was developed to reduce the Soviet dependency upon non-communist bauxite and to provide a source of potassium fertilizer.

The Russian process is very similar to the Alumet process and, in fact, Alumet purchased some technology from the Soviet Union. Both the Soviet process and the Alumet process utilize a caustic leach in place of the acid leach that other non-bauxite processes use. The Soviet process scheme initially roasts the ore to dehydrate the crystalline water. The pyrometallurgical treatment then continues to

MEXICAN ALUNITE PROCESS

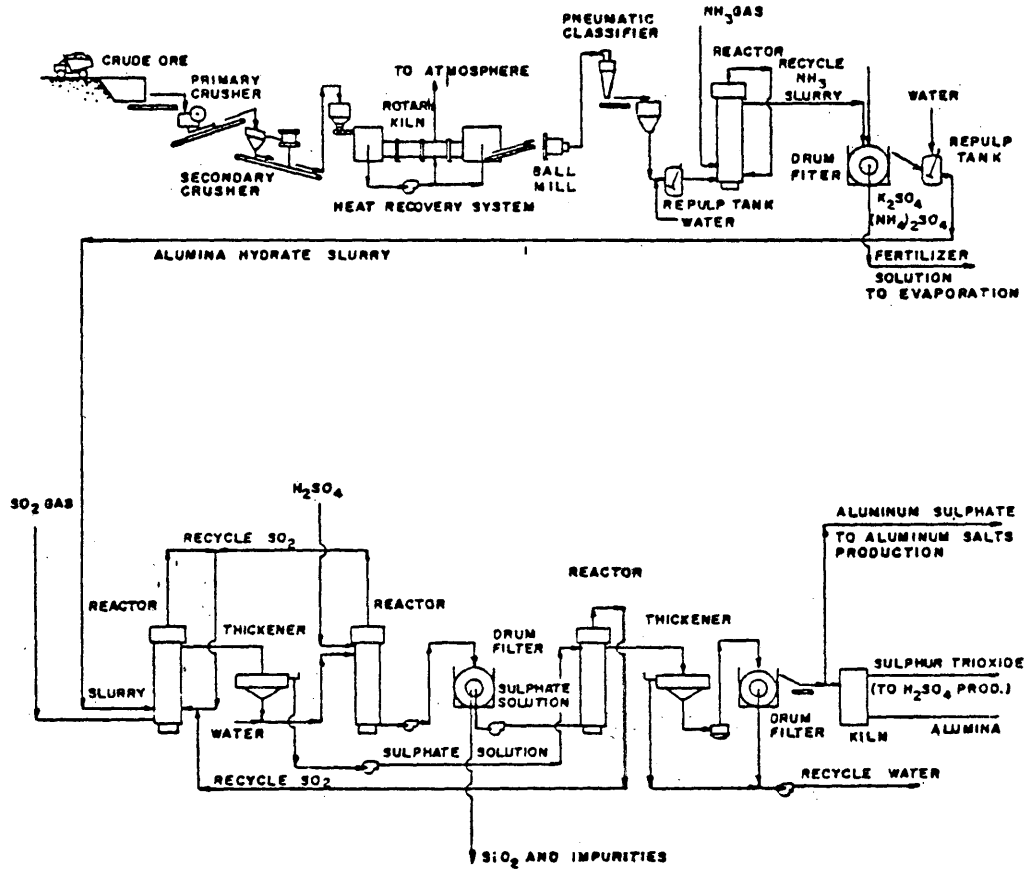


Figure 3 - Mexican alunite process flow sheet (Parkinson, 1971).

chemically reduce the ore. At this point the reacted ore is leached with a base and the solubilized products, alumina and potassium sulfate, are precipitated and recovered.

Alumet Process (Parkinson, 1974). Due to the fact that the remainder of this thesis deals exclusively with the Alumet process, no brief summary will be made of it here.

In conclusion to this chapter, it may be said that the underlying technological problem of the many alternate processes being developed have, for the most part, been solved. The remaining primary question of all of these processes is the relative economic feasibility as compared with bauxite on a commercial scale. Of course, all processes claim to be competitive with the conventional method of Bayer leaching of bauxite and Hall reduction to aluminum metal. None of the modern methods, with the exception of the Russian alunite process, has been proven commercially. The fact that the Russian process is currently producing aluminum on a commercial scale does by no means prove the economic feasibility of a similar process in the free world.

Therefore, the question of economic impact on bauxite producers due to non-bauxite aluminum production remains unanswered today. The remaining sections of this paper will examine the potential that the Alumet process has in becoming an economically viable commercial entity of the free world aluminum sector.

CHAPTER 2. PROCESS

Since the Alumet process will produce three products--sulfuric acid, sulfate of potash, and alumina, the process is relatively complex and involves both hydrometallurgy and pyrometallurgy (see flow sheet pictorially describing the process in Figure 4). Alunite rock is first crushed and dry ground to approximately minus 16 mesh. Next comes a series of roasting steps using standard fluidized beds. The alunite molecule must be rearranged to make both the aluminum and the potassium sulfate soluble in subsequent leaches. The sulfate associated with aluminum must be reduced to  $SO_2$  and made to pass from the system so it can be converted to sulfuric acid. The sulfuric acid will be combined with phosphate rock to produce phosphate fertilizer which should find ample markets.

Very narrow and complex constraints are imposed on the roast reactions. Temperature control must be precise--too low and the reactions will be too slow, too high and the alumina will be rendered insoluble.

After sulfuric acid, the first marketable product is recovered, the next step is to leach the potassium sulfate. The roasted ore is slurried with recycled liquor, and a relatively straight-forward water leach with an alkali added dissolves over 95 percent of the potassium sulfate.

The purpose of the alkali additive is to clean up the residual sulfate ion surviving the reducing roast. Sulfate of potash is recovered from the leach liquor by conventional crystallization. The leached residue continues to the second leach section and can be termed synthetic bauxite. At this point, the second marketable product is thus produced.

The remaining tails that was termed synthetic bauxite contain about 23 percent  $\text{Al}_2\text{O}_3$  and differs from natural bauxite as follows:

1. Processed alunite is lower in alumina content.
2. The alumina is soluble at atmospheric pressure (this aspect allows the aluminum values to be leached at a significantly lower processing cost due to the elimination of pressurized reaction vessels as compared with the conventional method).
3. Tailings are silica sand rather than "red mud" and are therefore much easier to settle, filter, and wash. The disposal of this residue causes less environmental impact as well.

4. There is no organic matter in roasted alunite, thus further reducing the processing costs as compared to the standard Bayer bauxite process.

The synthetic bauxite is then digested in recycled caustic soda solution and the tailings are separated. Pregnant liquor containing the alumina from the leach is pumped to large precipitator tanks. After the precipitation reaction is complete, the aluminum trihydrate (as it is now known) is classified and washed, using conventional equipment. The barren liquor is evaporated and recycled to digestion. Caustic and energy consumptions are similar to those experienced in bauxite plants; however, due to the atmospheric leach and the characteristic difference between the red mud (bauxite tails) and the alunite tails, overall processing is believed to be less in the alunite case (Thompson, 1976).

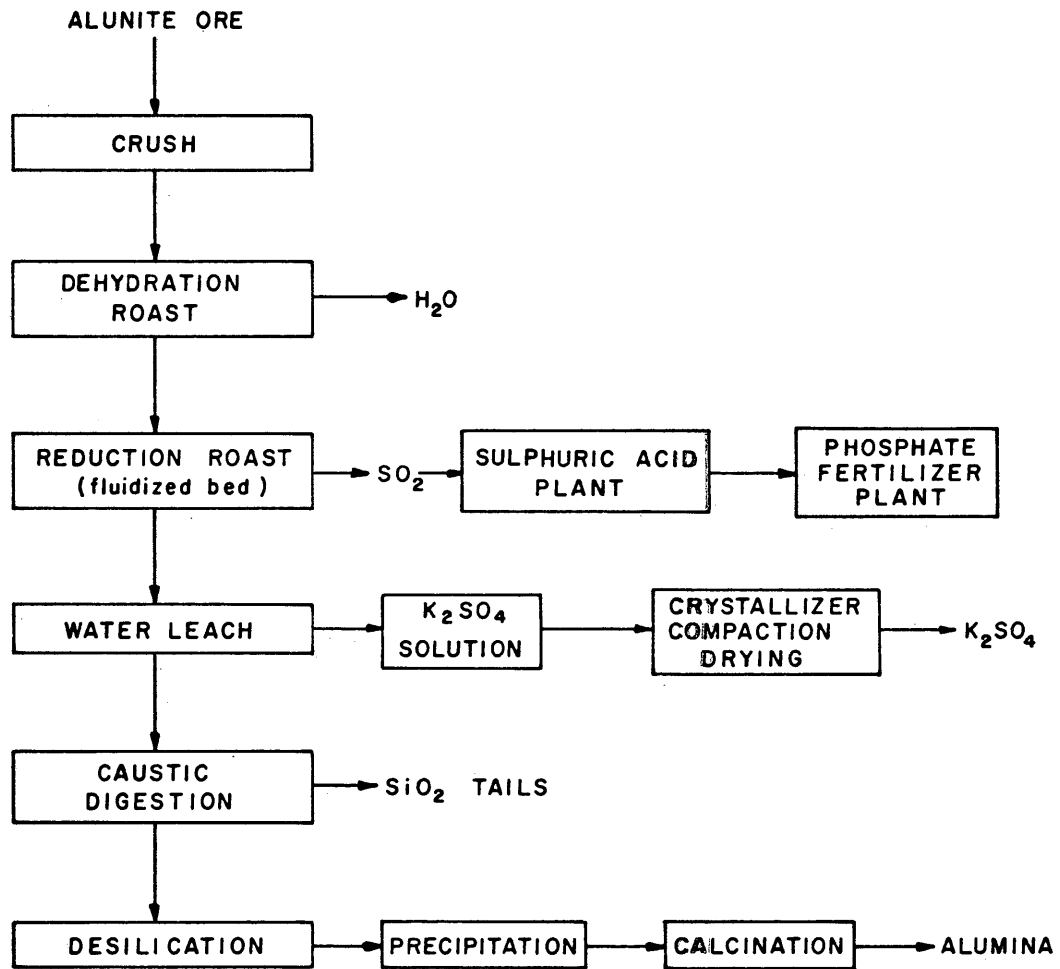


Figure 4 - The Alumet process flow sheet (Parkinson, 1974)

### CHAPTER 3. TECHNICAL FEASIBILITY

It is always difficult to make a clear distinction between completely technical and purely economic feasibility. A significant technical break-through may be even more significant in an economic sense. For example, if a process improvement was found technically that reduced the reagent cost by half, this would be both technically as well as economically significant.

In view of these considerations, the author has limited the discussion of technical problems to that type which would prevent the process from producing the desired products. In other words, for this report a chemical reaction that would not occur or machinery that could not be designed or fabricated to perform a particular function would be defined as technically infeasible.

The confidence of technical feasibility is sustained for the Alumet process mainly from tried and proven operations. There are two main processing sections in this process into which the technical problems can be divided, pyrometallurgy and hydrometallurgy.

First, in relation to the pyrometallurgical section, a very similar process as mentioned earlier has been in operation in Russia for the last ten years. The Russian process had a number of problems initially but through engineering and process changes including equipment design and reagent substitution these problems were eliminated or at least controlled successfully. The knowledge that was gained there has been passed on through visits by Alumet engineers and from formal purchased technology packages. Similar technology is also being used in relation to the Mexican U.G. alunite process.

The experience gained in previous plants is combined with expert advice from American engineering companies with many years experience in pyrometallurgy supplemented by experience gained from actual experimentation with alunite.

Second, concerning the hydrometallurgical section, the leaching schemes utilized incorporate proven techniques that have been in use for at least the last hundred years. The water leach section produces potassium sulfate much in the same manner that potassium sulfate is being produced today by at least a half dozen other companies.

The modified Bayer section again uses much of the technology that Mr. Bayer developed a century ago with the exception that the Alumet is simplified by not using pressure reactors.

The basic technology has, therefore, been proven and used both in this country in the case of the extraction areas and abroad in the case of the pyrometallurgical section. However, methods are being optimized in relation to Utah alunite and experience is being gained in operating the process. Definitive engineering data also continues to be gathered in preparation of the scale-up from the pilot plant to the production plant.

In conclusion, the technological feasibility aspect is, for all practical purposes, considered a proven process. But as mentioned earlier, the economic feasibility that must be considered in competition with bauxite and laterite ores does not enjoy the same level of confidence.

CHAPTER 4. RESERVES AND MINING PLAN

In order for the funds to be expended to develop a new metallurgical process sufficient mineable reserves must be available. The question of whether alunite is in sufficient quantity throughout the world to supply alumina demand in the long run is unanswered at present. However, there is enough alunite present in the United States today to warrant the development of a metallurgical process and the construction of at least one commercial scale production plant.

The ore deposit that made the process development feasible was discovered in Beaver County, Utah by Bill Walker of Earth Sciences Company, Inc., Golden, Colorado in 1971. The Beaver County deposits are located in the Wah Wah Mountains at an altitude of 6,300 to 7,300 feet. The deposit is located near Cedar City and Milford, Utah.

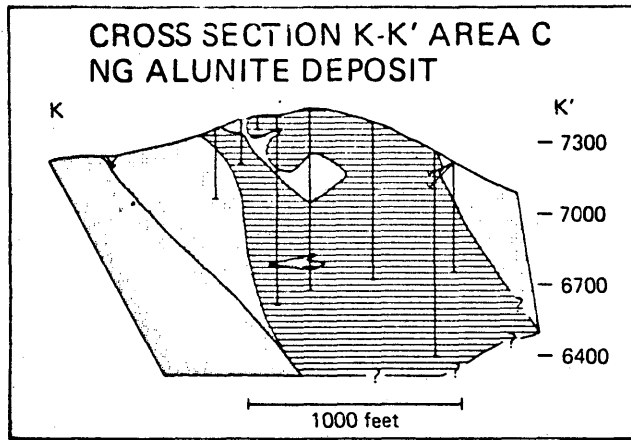
Shortly after the discovery was made, the company began exploration drilling and has proven a deposit of more than 100 million tons. Exploratory drilling at four other peripheral locations in the county has established the presence of ore zones over an area of more than 25 square miles.

Total resources in the five explored locations are estimated at 680 million tons, and the inference is that there is much more ore in the area.

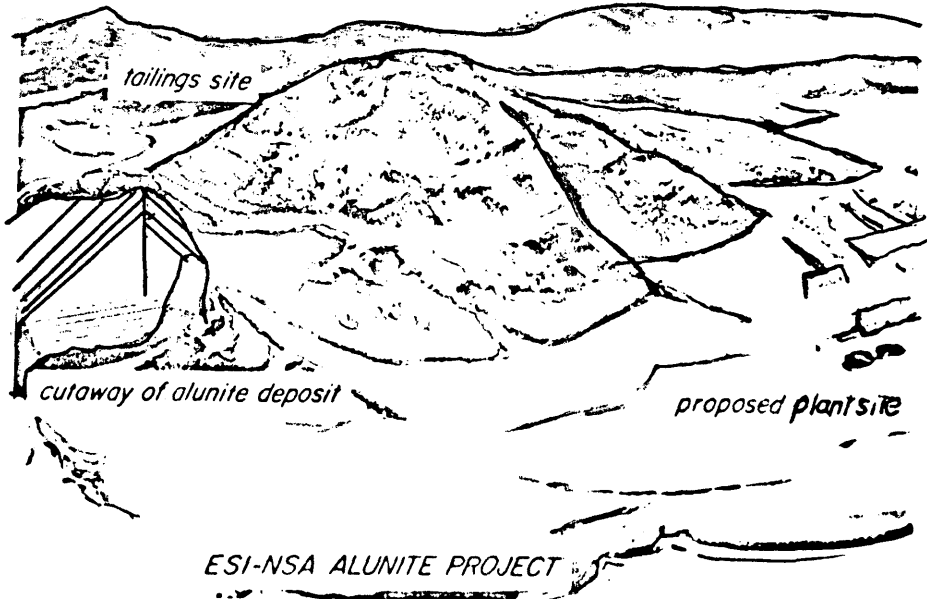
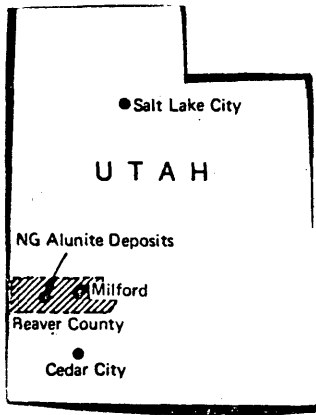
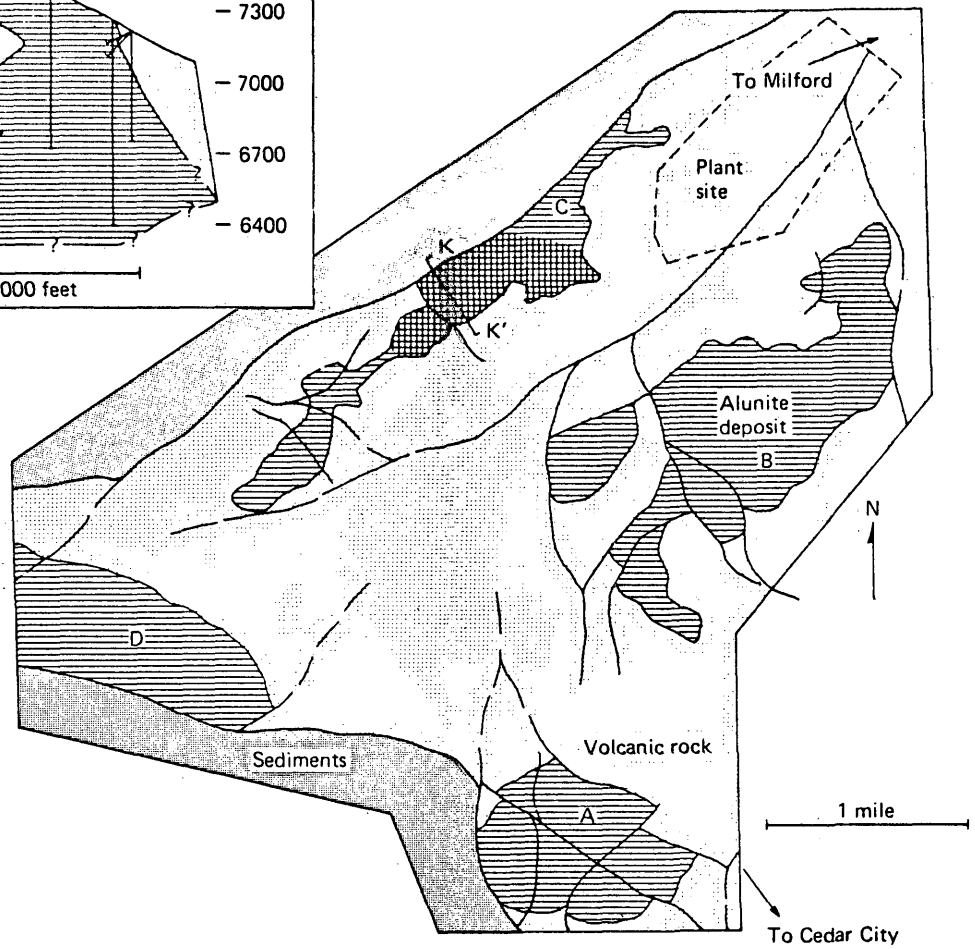
Earth Sciences have obtained or is negotiating for permits, leases, and mining claims on 10 to 15 alunite properties in Utah, Arizona, Nevada, Colorado, and California. More than half of these look favorable for mining and subsequent alumina production.

The mining plan has not been finalized on the initial mining operation as yet but since the deposit is large with practically no overburden, an open pit will be developed. It is probable that the alunite deposit will be bench mined. Haul roads will be built to truck the ore to the plant (see Figure 5).

It is likely that the ore will be drilled, blasted, and loaded by power shovel or front-end loader into haulers, but a mobile crusher and conveyer system is also a possibility. A unit train similar to the type used by Western Paving of Denver to haul gravel from Lyons to Denver is also being considered. In the final analysis, the system that can demonstrate the better expected economics will be implemented.



### GEOLOGY OF NG ALUNITE DEPOSITS



**ESI-NSA ALUNITE PROJECT**  
**ARTIST'S CUTAWAY DRAWING OF N.G. DEPOSIT MINING PLAN**  
*Levelling mountains and making meadows.*

Figure 5 - Geology of NG alunite deposits (Thompson, 1976).

## CHAPTER 5. DEMAND

Because the Alumat process produces three products, the demand for all three of these products is important to the economic well-being of the commercial plant. Therefore, the world-wide demand for these three products today and the future is examined below.

### Aluminum

In estimating the world consumption of aluminum, one can assume that the consumption will continue to rise to about 20 kilograms per year per capita on the average. This is indicated by developing nations in the recent past. Considering the increasing world population, the world consumption for aluminum would be five times higher in year 2005 than it is now (Cohen, 1976).

Historically, the demand for bauxite has continued at a brisk pace as Table 1 indicates (U.S. Bureau of Census, 1972) These data indicate that approximately a ten-fold increase occurred in the value of bauxite imported for consumption in a 20-year period from 1950 to 1970. This increase in demand during this period suggests that future demand for alumina will continue.

TABLE 1Value of Bauxite Imported for Consumption  
in the United States

<u>Year</u>	<u>Value (in thousands of dollars)</u>
1950	15,730
1955	63,656
1960	78,024
1965	142,989
1967	151,418
1968	140,228
1969	165,639
1970	156,362

On a short term basis, the recent recession of 1974-1975 has reduced the demand. Domestic production of primary aluminum metal in 1975 decreased 20 percent from 4.4 million metric tons valued at more than three billion dollars, to 3.5 million metric tons, valued at slightly under three billion dollars. While during this time imports dropped 24 percent and the U.S. produced at only 74 percent of capacity, a 43 percent decrease in exports caused the United States to remain a net importer of aluminum (Mining Engineering, 1976).

As the economy picked up during the latter quarter of 1975 and the first half of 1976, aluminum demand increased. For 1976 as a whole, domestic production is expected to rise about 25 percent to 6.25 million tons (Blumenreich, 1976).

An important factor that is expected to increase the demand for aluminum significantly is greater use of it in the automobile industry, brought about primarily by the desire of the consumers for better gas economy in view of higher prices for fuel and the threat of further oil embargos by OPEC.

Other savings besides fuel economy could be realized by lighter autos, including reduced brake wear, tire costs, and even registration fees in some states. When the car is junked, the aluminum could be recycled. By the end of this decade, industry experts foresee aluminum consumption in automobiles rising by 40-50 percent to a minimum of approximately 120 pounds for each vehicle. The average 1976 American car used about 90 pounds of aluminum per unit (Chemical Engineering, 1976).

Aluminum use will replace cast-iron for engine blocks and copper for radiators in the near future. Also, aluminum industry watchers feel that lightweight metal rates as a strong contender for hood and rear decklid applications in 1977 model year cars. In fact, current (1976) models of General Motor's Oldsmobile Toronado and Plymouth's Feather Duster already feature aluminum hood and deck inner panels.

The increased use of aluminum in auto manufacturing is partly due to the development of an organic fluid used as

a die lubricant that is expected to significantly improve the high-volume stamping procedure used in past production of the auto.

At the moment, as the Oldsmobile and Plymouth moves indicate, aluminum is replacing steel in the auto industry which will place significantly improved demand on the aluminum production capacity. This new demand, coupled with the traditional growth that aluminum has experienced in the past, demonstrates the continued firm market position of aluminum.

In fact, United States aluminum producers posted higher prices in April of 1976. Reynolds led off on April 21 by announcing a three-cent increase per pound for aluminum ingot to 44 cents, effective for orders the following day and for shipments on May 17. Most mill product prices were also increased. Within the next few days, most United States producers and Canada's Alcan posted price increases similar to Reynolds'

Aluminum is demanded in the building and construction trade. It is also used in transportation, electrical equipment, containers and packaging, consumer durables, machinery and equipment, and now automobiles (body, motor, and radiators) This demand, combined with the shrinking world reserves of bauxite and foreign intervention of shipments including

cartel action, further insure a market for alumina from alunite.

One of the major justifications for researching alternate raw material is the existence of the bauxite cartel. The existing real threat of foreign reduction or restriction of bauxite production and shipments, similar to the activities of the Organization of Petroleum Exporting Countries, poses serious problems for the aluminum industry. The International Bauxite Association (IBA), formed in 1974, has now eleven members headed by Henri Guda as Secretary General. Table 2 lists these countries and their bauxite production percentage (Eight Mineral Cartels, 1976)

The IBA member countries produce over 80 percent of the bauxite used by the free world. Although the International Bauxite Association has not made a formal agreement on a uniform pricing formula for pricing bauxite it has succeeded in increasing revenues from the red ore they mine. Aluminum Company of America (ALCOA), the largest United States aluminum concern, states that the industry's bauxite costs have more than doubled since 1970 (Wall Street Journal, 1976).

It is interesting to note that the Alumat process, due to its unique situation, stands to gain financially if a price increase occurs in either the aluminum market or the bauxite market or better yet--in both.

TABLE 2

## Bauxite Reserves and Bauxite Production

	Proven Bauxite Reserves		1973 Bauxite Production	
	(millions Mt)	(% of Free World total)	(000 st)	(% of Free World total)
<b>IBA members:</b>				
Australia	4,700	30.6%	19,395	28.3
Dominican Republic	60	0.4	1,263	1.8
Ghana	330	2.1	344 (a)	0.5
Guinea	3,500	22.8	3,000	4.4
Guyana	200	1.3	4,100	6.0
Haiti	25	0.2	871	1.3
Jamaica	1,000	6.5	14,870	21.7
Sierra Leone	120	0.8	764	1.1
Surinam	500	3.3	7,654	11.2
Yugoslavia	250	1.6	2,389	3.5
IBA totals:	<u>10,685</u>	<u>69.6</u>	<u>54,650</u>	<u>79.9</u>
<b>Other producers:</b>				
Greece	700	4.6	3,261	4.8
India	130	0.8	1,397	2.0
Indonesia	<u>500 (b)</u>	<u>3.3</u>	<u>1,549</u>	<u>2.3</u>
<b>13 Country totals:</b>	<u>12,015</u>	<u>78.2</u>	<u>60,428</u>	<u>88.9</u>
<b>United States:</b>	<u>40</u>	<u>.3</u>	<u>2,118</u>	<u>3.1</u>
<b>Free World:</b>	<u>15,360</u>	<u>100.0</u>	<u>68,428</u>	<u>100.0</u>

(a) Exports only.

(b) Includes some inferred reserves.

In addition to the threat of cartel action, the serious problem of foreign organized labor is also a consideration in assuring ample supplies to free world aluminum smelters. For example, in Jamaica the labor union is demanding that the Aluminum Company of America build each worker a new house. Strife between labor and management is also causing this company difficulties in obtaining qualified management personnel that are willing to relocate in Jamaica for a reasonable period of time. Other countries exhibit the same unreasonable labor demands and violent reactions toward management personnel and their families.

#### Potash

The second marketable product produced by the Alumet process is potassium sulfate, better known in fertilizer markets as sulfate of potash, which is used extensively throughout the world as a plant nutrient. Vegetation requires both sulfate and potash in varying amounts depending upon the specific type of plant in question and the stage of maturation.

The world demand for potash is improving due primarily to two considerations. First, world demand for food is, of course, increasing due to the population growth and higher standard of living of many nations, as compared to one or two decades ago.

The second factor stems from the political situation of Saskatchewan, Canada. The provincial government of Saskatchewan, the world's leader in potash production, in a move that surprised the free world, increased the tax burden of all eleven potash producers of that area to an amount that makes potash production financially unattractive. In fact, the government of Saskatchewan is currently attempting to nationalize the properties producing potash, with the final threat of expropriation.

Expansion is not likely by the potash producers of Saskatchewan as the tax load now limits their average rate of return on original investment to only five percent and much less on the basis of present equipment and construction costs (Lyon, 1976)

Potash demand in the world is expected to increase from about 19 million tons of contained  $K_2O$  in 1974-1975 to 20 million tons in 1975-1976 (Lyon, 1976)

Considering the above items, the market position for an alternative source of potash, as was the case of aluminum, also enjoys a favored outlook for the future.

#### Sulfuric Acid

During the first process step of the pyrometallurgical rearrangement of the alunite molecule,  $SO_2$  is liberated which is easily converted to sulfuric acid. Due to the remote production location in relation to industrial centers, this

sulfuric acid could probably not be marketed in a profitable manner because the freight charges of the heavy corrosive liquid acid would be prohibitive. With this in mind, the sulfuric acid will be converted to phosphoric acid utilizing phosphate rock from a wholly-owned mine in Idaho on both private and Federal leases. Therefore, the demand question here is not concerned with the sulfuric acid market but rather the demand for phosphate fertilizer.

Phosphate is expected to continue to be demanded due to many of the same reasons mentioned under the potash section. As with the case of potash, there is no substitute for phosphorus in agriculture. Because of the world's rapid population expansion, all soils under cultivation require replenishment of nitrogen, phosphorus, and potassium. Without replenishment harvests are doomed.

Until 1973, profitability in production of phosphate was a sometimes thing. Then the specter of a worldwide phosphate shortage was perceived in late 1973 and the prices began to rise as the following table indicates (Hoppe, 1976):

TABLE 3

Phosphate Price Fluctuations During Recent Past

<u>Date</u>	<u>Phosphate Price</u>
July, 1972	\$ 10-11/ton
January, 1974	40/ton
January, 1975	65/ton
Current price, 1976	\$41-45/ton

Whatever the short term outcomes of this price bouncing is, the long term effect should be greater production at reasonable profits (Hoppe, 1976)

The Alumet process also has a great deal of flexibility, involving the quantities and proportions of sulfuric acid and potassium sulfate that are produced. There is flexibility in the type of phosphate fertilizer marketed, depending upon the product the consumer demands.

CHAPTER 6. PROCESS ECONOMICS

As was mentioned earlier, the Alumet process must be capable of competing economically with bauxite. There are, however, other considerations besides being strictly competitive on a dollar-for-dollar basis. For example, with the Alumet process the participating companies can become more fully vertically backward integrated by having a captive domestic source of raw material for aluminum (National Steel Annual Report, 1973). Since all the known deposits of domestic bauxite are owned by other aluminum companies, domestic vertical integration is impossible without the development of an alternative aluminum source. Without a domestic source of raw material, the production of aluminum by the parent companies of Alumet (as is the case with most North American aluminum producers) are at the mercy of the International Bauxite Association cartel.

Be that as it may, in the free world, and especially in the United States, for an enterprise to survive and be viable, it must be capable of making money for the investors. In short, the major question becomes, is alunite, in fact,

an ore when ore is defined as a mineral that can be mined and processed at a profit?

To attempt to predict the economic well-being of the Alumet process, the following very preliminary economic evaluation is presented. A more refined evaluation could be made but questions of proprietary information would arise and a very detailed evaluation would be beyond the scope of this paper.

To determine if this process is truly economically feasible, approximating values on a conservatively high cost basis is believed to better indicate the future of the commercial process.

A proposed production goal of the commercial plant is 500,000 tons alumina per year. To avoid revealing details of prices and contract negotiations, price quotations from a recent "Chemical Marketing Reporter" will, in this paper, be used (Chemical Marketing Reporter, 1976). No attempt will be made to predict future prices; thus, any possible bias will be eliminated. In other words, this evaluation will be made as if the products were sold at today's published prices and reagents were bought at today's published costs.

Income is calculated on the basis of the constituents contained in the ore feed and adjusted to the expected level of recovery.

Income

The commercial plant will be designed to produce 500,000 tons of alumina per year. All other products are calculated in the average ratio of the reserve assay for the first 20 years of production.

Alumina: 500,000 tons per year at \$118 per ton -- \$59,000,000

Potassium Sulfate: 380,000 tons per year at  
\$87.50 (minimum 50% K<sub>2</sub>O) per ton -- 33,250,000

This process is capable of producing consistent minimum 52 percent K<sub>2</sub>O grade potassium sulfate which brings a premium price of \$97.50 per ton, but to remain conservative in this analysis the lower figure is used.

Sulfuric acid: Marketed as a phosphoric compound but for evaluation purposes the price for sulfuric acid will be used. Approximately one million tons of sulfuric acid will be produced. One million tons at \$32.60 per ton -- \$32,600,000

Total income \$124,850,000

There are methods to increase income from the plant by shifting production emphasis from one product to the next, depending on the market condition. Due to secrecy considerations, these alterations cannot be discussed here.

Operating Expenses

Reagent Expense:

Caustic: \$11,600,000

Reductant and miscellaneous: 16,800,000

All reagent expenses are calculated at the higher expected yearly consumption values, using the price quoted in the same "Chemical Marketing Reporter" that was used for the income calculations. These costs also include estimated freight charges delivered at the plant.

Coal: \$7,000,000

The Alumat Company has its own coal supplies located in Utah close to the alunite site. This figure is calculated at the consumption estimated necessary for the plant to operate and with a cost of production and transportation that is thought competitive with other coal of similar analysis available in the area. The Alumat plant will have its own power station that may even supply power to surrounding facilities and communities at a profit.

There are many opportunities to reduce the reagent cost listed above, including an ion exchange system that will scavenge bleed streams, thus reducing pollution problems as well as cutting reagent costs. With more efficient operation of the process being optimized currently in the pilot plant, further reduction in reagent costs will be realized. But for the purpose of preliminary economic evaluation and in order to escape proprietary considerations, these sophistications in the process will not be included now.

Total annual estimated reagent costs  
including coal and freight charges --\$35,400,000

### Personnel Costs

Estimated number of personnel will be 1200. The yearly average labor burden including pay, FICA, Federal Unemployment insurance, workmens compensation, etc. per employee is estimated at \$20,000. It is realized that a number of the people will not make that much, a few will earn more, but including fringe benefits and employment compensation, this figure is believed to be conservatively high. The number of employees listed is also probably on the high side, especially considering the degree of automation process plants are obtaining today.

Total personnel costs	1200 x \$20,000	\$24,000,000
Total operating costs	\$24,000,000+\$35,500,000	\$59,400,000

### Finance Requirements

Capital items that will be required of the Alumet commercial production plant as now planned are:

Phosphate mining facilities

Phosphate beneficiation complex including pipeline,  
calcination plant, and railroad

Alunite mining facilities

Crushing and grinding plant

Roast plant

Acid plant with phosphoric acid conversion plant

Sulfate of potash production plant

Alumina production plant

Railroads

Power plant

Coal mine

Roads

Water supply

Communication facilities

Site preparation and fencing

Tailings ponds

Other offsite facilities

Spare parts

Capital costs of the entire Alumet complex as described above are expected to be in the general order of \$400 million as of the first quarter of 1976.

#### Economic Evaluation

Based on the data listed above, the following evaluation is made on a yearly basis. Escalation of plant incomes and operating costs during the twenty-year evaluation period will be assumed to cancel the effects of each other or in other words be a washout. Due to the preliminary nature of estimation to determine whether this process is approximately economically feasible, no investment tax credits or similar items such as pollution control write-offs will be

calculated. All development costs of the research and exploration are being deducted from current earnings of the parent companies and will, therefore, not be taken into consideration in the Alumet process economic evaluation. No salvage or working capital return will be credited because the life of the project will continue past the twenty year evaluation period.

Yearly Economic Evaluation

Sales -----	\$124,850,000
Operating costs -----	59,400,000
Depreciation -----	<u>20,000,000</u>
Taxable income before depletion -----	45,450,000
50% depletion limit -----	(22,725,000)
15% depletion -----	18,727,500
Gross profit -----	26,722,500
Taxes at 50% -----	<u>13,361,250</u>
Net profit -----	13,361,250
Depletion -----	18,727,500
Depreciation -----	<u>20,000,000</u>
Net cash flow -----	\$ 52,088,750

There is no percentage depletion allowance at the present time approved for alunite but legal counsel is of the opinion 15 percent is a satisfactory estimate.

Due to the large ore deposit and the long duration of this project cost depletion is not considered.

By interpolation after tax return on investment, using the estimated figures developed above which are admittedly high in the case of the operating costs, the rate of return comes to approximately 12 percent.

The fact that gross cost estimates can be made with no attempt to decrease the cost where obvious fat exists (\$20,000 per man per year and assuming the entire \$400 million investment occurs in year one, for example), still have a 12 percent after tax return on investment indicates this process at present prices appears to be economically feasible.

If the demand increases for the products that will be produced are as predicted in the demand section and prices increase as they should with demand pressures increasing, the economical feasibility position should improve in a like manner.

The fact that three major products are produced further strengthens the financial position of the process. This diversification reduces the risk of having all the profit eggs in one basket. The flexibility of the process also allows the product with the higher price to be produced in greater quantity, depending upon the operating parameters of the plant and the assay of the ore fed to the plant.

TABLE 4

Rate of Return Analysis  
(10% Present-Worth Factor)

<u>Year</u>	<u>After Tax Cash Flow (millions)</u>	<u>Factor</u>	<u>Present-Worth (millions)</u>
1	\$52.088750	.909	\$47.3
2	"	.826	43.0
3	"	.751	39.1
4	"	.683	35.6
5	"	.620	32.3
6	"	.564	29.4
7	"	.513	26.7
8	"	.466	24.3
9	"	.424	22.1
10	"	.385	20.1
11	"	.350	18.2
12	"	.318	16.6
13	"	.289	15.1
14	"	.263	13.7
15	"	.239	12.4
16	"	.217	11.3
17	"	.197	10.3
18	"	.179	9.3
19	"	.163	8.5
20	"	.148	<u>7.7</u>
			\$443.0
Total investment (assumed to take place at time zero) -----			\$400.0

TABLE 5

Rate of Return Analysis  
(15% Present-Worth Factor)

<u>Year</u>	<u>After Tax Cash Flow (millions)</u>	<u>Factor</u>	<u>Present-Worth (millions)</u>
1	\$52,088750	.870	\$45.3
2	"	.756	39.4
3	"	.658	34.3
4	"	.572	29.8
5	"	.497	25.9
6	"	.432	22.5
7	"	.376	19.6
8	"	.326	17.0
9	"	.284	14.8
10	"	.247	12.9
11	"	.215	11.2
12	"	.187	9.7
13	"	.162	8.4
14	"	.141	7.3
15	"	.122	6.4
16	"	.107	5.6
17	"	.093	4.8
18	"	.081	4.2
19	"	.070	3.7
20	"	.061	<u>3.2</u>

\$326.0

Total investment (assumed to take place  
in year zero) ----- \$400.0

CHAPTER 7. SENSITIVITY CONSIDERATIONS

Before a decision is made to build a commercial plant involving an investment on the magnitude of \$400 million, the sensitivity of the most salient parameters must be investigated. Sensitivity analysis refers to analysis of how an investment's profitability is affected by variation in each of the major parameters (Stermole, 1974)

In every project a change in a particular variable may influence the profitability of the project much more than changes in others. For the Alumet project the cost and consumption rate of reagents is believed to be the most critical. As can be noted from the operating expenses mentioned under the process economic section reagent, cost including caustic, reductant, coal, and miscellaneous reagents amount to an annual cost of \$35,400,000.

A small increase in either the amount of reagents used or the price of the reagents that Alumet must pay would have a large impact to the overall profitability of the project.

Reagent Expenditure Sensitivity Analysis

Assuming the price or consumption rate of reagents increase or a combination of both, the following sensitivity analysis is presented:

<u>Increase Reagent Expenditure (%)</u>	<u>Annual Reagent Cost</u>
Increase of 10% over estimated cost	= \$38,940,000
Increase of 20% over estimated cost	= 42,480,000
Increase of 40% over estimated cost	= 46,020,000

By incorporating these increased reagent cost figures into the yearly operating expenditures, the following net cash flow would result.

<u>Reagent Cost Increase</u>	<u>Net Cash Flow</u>
10%	\$50,318,750
20%	48,548,750
30%	46,778,750

Then, by discount return on investment analysis, the following DCFIs result if the price of reagents and/or the consumption rate increases.

<u>Reagent Cost Increase</u>	<u>DCF I</u>
10%	11.2
20%	10.5
30%	9.9

As can be noted, an increase in either the price of reagents, an increase in the consumption of reagents, or a combination of the two can seriously decrease the expected rate of return. However, it should be kept in mind a savings in this area would similarly produce an increased rate of return.

The recovery percentage, or yield, of all processing plants directly affect the revenue received and, in turn, the profitability of the enterprise. However, in the case of the Alumet project the economic analysis cited has taken a conservative position on the recoveries and the level of confidence in this area is believed to be such as to render this consideration to be less sensitive than the reagent cost factor. The fact that three products are being marketed also tends to relax the yield sensitivity. If the sulfuric acid yield is low in the first process step, the second product, potassium sulfate, will be that much higher.

Personnel costs again do not threaten the project excessively. In today's modern processing, industry labor-saving techniques are abundant and proven. The labor cost ratio to finished products is also low. The fact that little other industry exists in the proposed processing location lessens the competition for labor and reduces the sensitivity of high personnel costs in relation to the overall profitability of the project.

Other factors such as ore grade and reserves, construction costs, and inflation play a roll in the risk of the project but the overall potential of producing alumina from a domestic captive source allows these factors to be acceptable when the only other alternative is to depend on foreign sources for alumina.

CHAPTER 8. STRATEGIES OF PRODUCTION

The quest for an economical substitute for bauxite has created something of a boom in research in recent years. If any of the many projects proves successful, including the alunite project, significant pressure may be brought upon the bauxite producing countries. This market pressure would be especially significant in the case of Surinam and Jamaica. These two countries supply approximately 33 percent of the free world bauxite production, and the revenues received from this production account for the major portion of their gross national product. This revenue also comprises the major portion of foreign exchange that is severely needed by these developing countries, because they have little else to sell that is demanded by the world market.

It is only understandable that these developing countries wish to maximize the return from their bauxite shipments, but as the price of bauxite increases, economic substitutes to it become more of a possibility. These substitutes, however, occupy a particularly precarious position.

The dilemma involved in introducing substitutes is a real and dangerous economic position to be trapped in. The United States' companies realize they could be at the mercy of foreign producers if the prices of bauxite were manipulated.

High bauxite prices trigger the expensive switch by companies to produce alumina from other sources, as well as using the same substitutes for purposes other than aluminum production. But if the foreign suppliers lowered their prices to the true production cost level, the substitutes would become too expensive to use; it may leave the domestic industry holding the proverbial bag. The Soviet Union used similar tactics against some American tungsten mining companies in the early 1960's.

With the manipulation possibility in mind, the minimum price possible for bauxite should be examined. It is estimated that Caribbean bauxite can be delivered to the United States for \$19 to \$27 a ton (Wall Street Journal, 1976). An average of these figures gives a minimum production cost of \$23 per ton for bauxite delivered to the Gulf Coast near alumina processing centers. This means a substitute for bauxite must be provided that costs no more than \$23 per ton, to be free from fear of price slashing.

In the case of alunite, which is little more than half the grade of bauxite in contained alumina, the synthetic bauxite mentioned under process description must be produced for no more than \$13 a ton.

Due to the co-products of the Alumet process, it is believed that this price constraint can be met. That is to say, the initial processing cost which consists of mining the ore, crushing it to approximately 20 mesh, pyrometallurgical treatment, and potassium sulfate extraction will be paid for by the co-products sales (sulfuric acid and potassium sulfate) This leaves the \$23 to make-up any additional costs experienced in the initial processing; or it offers a cushion for reductions if they occur in co-products.

The actual alumina production is believed to cost about the same using either the synthetic bauxite or actual bauxite when the modified Bayer leach circuit is utilized rather than the high pressure equipment currently employed in the conventional Bayer plants. The tailings of the Alumet process are also less difficult to filter, wash, and dispose of. All in all, the reduced grade of the synthetic bauxite is believed to be offset by other advantages not enjoyed by bauxite.

Cell-grade alumina can be recovered even if the International Bauxite Association reduced the price of bauxite drastically. This assumes the price of the co-products do not suffer a significant cut at the same time.

The one recognized problem Alumet alumina has is competing with alumina plants built years ago with government

money and/or with lower interest rates. These older plants can produce alumina cheaply due to the plants' being paid for and start-up costs being a thing of the past. The industry in this position has a favored vantage point, but if they, including Alumat's parent investors, do not move soon to add capacity, even at higher costs, they will find themselves losing their market share and industry strength, although the total profit may be higher for a limited time.

#### Impact of Alunite on Bauxite Producing Countries

The bauxite producing countries have good reason to keep a close watch on the substitute research activity. The major factor in cartel endeavors that insures strength is the relative absence of production of the controlled product by nations not participating in the cartel. This, indeed, is the specific purpose of most of the research now being conducted to produce alumina from minerals other than bauxite. To have a captive source of alumina that is independent of the International Bauxite Association would give any aluminum company in America definite strength and independence.

Can alunite provide this strength and in so doing, weaken the bauxite cartel? Alunite can provide a captive and domestic source of alumina to its investors, but its ability to significantly weaken the bauxite cartel in the near future is perhaps a bit optimistic. The Utah project, if constructed

as planned to supply 500,000 tons of alumina per year, will supply approximately 5 percent of the alumina currently consumed in the United States.

If each alunite plant were constructed on the same scale, it would require twenty plants to supply the total alumina now used. Twenty alunite plants at this time is a bit unrealistic; however, the Alumet plant would supply the total alumina requirement of the National Southwire Aluminum Company with about 150,000 tons per year in excess for sale to other companies.

This total backward integration of raw material, independent of foreign intervention, could place the parent company in a superior economic position if the cartel action becomes worse or an embargo were to take place. Through the co-product sales of Alumet process, greater diversification can be obtained for the three partners of the Alumet Company.

## CHAPTER 9. CONCLUSION

The purpose of this thesis was to review the economic factors believed most relevant to the success or failure of the Alumet alumina from alunite production process. After considering these factors, the purpose was then to predict the final decision of the Alumet management concerning the practicability of constructing the commercial production complex.

In the remaining pages each factor will be re-examined and its relative importance will be assessed.

### Other Non-Bauxitic Alumina Processes

Comparing the Alumet process with the other non-bauxitic processes, one fact stands out: The Alumet process has co-product sales that other process schemes do not have on the same scale. The co-product sales greatly increase the revenue of the process and adds an element of diversification to the investor companies. This single fact is believed to be one of Alumet's strongest assets in relation to other non-bauxite sources.

### Technical Feasibility

The fact that Russia currently has a commercial scale alunite alumina processing plant and that it has produced alumina since 1966 rather firmly proves the technical feasibility of producing cell-grade alumina from this particular non-bauxite ore. The Alumet process development division is also producing alumina, which further supports the fact that the free world has the technical skills and knowledge to produce alumina from Utah alunite.

### Mining Reserves

Regardless of the prices, if the mining reserves are non-existent or insufficient, the process will fail economically. Fortunately, this is not the case with alunite in the United States. The initial plant proposed for the Utah Wah-Wah valley has approximately 700 million tons of alunite in reserve to assure the project ample feed ore. This is sufficient ore to feed the proposed plant for at least 300 years.

### Demand

The continued demand for all three products produced from the Alumet process, alumina, potassium sulfate, and sulfuric acid is virtually assured.

### Aluminum

The past demand performance of aluminum as a substitute metal is universal and certainly proven. Recycled aluminum may supply some of this demand but the new and additional uses of the light metal in the auto industry, combined with the shrinking world-wide reserves of bauxite and likely cartel action, eliminates the risk of a serious long-term slump in demand for aluminum. This is especially true for a completely domestically supplied aluminum.

### Potassium Sulfate

The world's needs for more food, translates into a world needing some fertilizer, in turn assures a continuing need for potassium sulfate. The recent action of Saskatchewan, which is causing a shrinking potash production trend, suggests both a short term increase in demand stemming from government actions, and a long term demand due to the continued need for more food throughout the world.

### Sulfuric Acid

The sulfuric acid product, when converted to phosphate fertilizer via the wet dissolution method, enjoys the long-term increase in world demand much in the same manner as the potassium sulfate product does.

The combination of supplying both potassium and phosphate in respectable quantities affords additional market advantages to the parent companies of Alumet. Having two out of the major three fertilizer ingredients--nitrogen, potash, and phosphate--certainly offers an opportunity for a fertilizer division in the corporate structure of a conglomerate.

#### Process Economics

The final analysis of the project, of course, is the actual process economics. This single aspect is extremely complex and has necessitated the work of a team of development engineers for more than a year. The complexity has also required outside contracts with many independent engineering companies involving various feasibility studies and a matrix of processing, marketing, and mining variables. The case presented in this thesis is admittedly simple but nonetheless believed to be accurate and realistic.

The fact that this conservative evaluation results in an approximately 12 percent return on investment after tax indicates an economically feasible project.

#### Potential

The potential for backward integration of producing domestic alumina from a source other than bauxite is an extremely significant aspect. Considering the world-wide

market that aluminum enjoys and the shortage of bauxite in America (and perhaps soon the world), the desirability of producing a significant quantity of raw material that is non-dependent on other companies or countries adds a tremendous incentive to this product.

The discounted rate of return is admittedly low, however, the possibility of licensing the technology to other nations that desire the co-products as much or more than the alumina, offsets the low return on the initial investment to point of overcompensation. X

When all these factors are taken in aggregate and considered as a total, the conclusion of this thesis can be simply stated. It is the opinion of this author, as reflected in this thesis, that the decision by the controlling partners to construct the commercial plant will, in fact, be made in the near future.

BIBLIOGRAPHY

1. Blanc, B.A., Leucite as a source of alumina, potash and silica, Institution of Chemical Engineers, London, Vol. 9, 1931, p. 49-62.
2. Blumenreich, S.M., Aluminum--economic revival will strengthen markets through 1976 and 1977, Engineering and Mining Journal, Vol. 177, No. 3, March 1976, p. 54-84.
3. Chemical Engineering, Auto makers drive toward lighter materials, March 29, 1976, Vol. 83, No. 7, p. 74.
4. Chemical and Engineering News, PUK process, April 7, 1975, p. 20-21.
5. \_\_\_\_\_, Toth process, Feb. 26, 1973, Vol. 51, p. 11-12.
6. Chemical Marketing Reporter, Market Reports, Vol. 209, No. 20, May 17, 1976, New York, p. 33.
7. Chemical Week, Russian metals know-how finds a home in U.S., Feb. 4, 1976, p. 24.
8. Cohen, J., and Mercier, H., Recovery of alumina from non-bauxite aluminum-bearing raw materials, AIME Publication, Light Metals, 1976, Vol. 2, p. 3-18.
9. Engineering and Mining Journal, Aluminum plant using new toth process to be built in Europe, Vol. 174, No. 8, Aug. 1973, p. 26.
10. \_\_\_\_\_, H-plus alumina process, Vol. 176, No. 2, Feb. 1975, p. 33.
11. \_\_\_\_\_, New alumina process, Vol. 173, No. 6, June 1973, p. 175.
12. Fleisher, A., Kalunite process, AIME Technical Publication, No. 1713, 1944.
13. Hoppe, Richard W., Phosphates are vital to agriculture, Engineering and Mining Journal, May 1976, p. 80.

14. Kurtz, H.F., Mineral yearbook, United States Government Printing Office, Vol. 1, Washington, D.C., 1970.
15. Lyon, F.D., Potash, Engineering and Mining Journal, March 1976, p. 114-115.
16. Mining Engineering, Bauxite and alumina, March 28, 1976, Vol. 28, No. 3, p. 27-28.
17. \_\_\_\_\_, Metals production, Vol. 28, No. 2, Feb. 1976, p. 15.
18. McGraw-Hill, Inc., Eight mineral cartels, New York, 1976, p. 113-130.
19. National Steel Annual Report, National Steel Publishing Co., 1973.
20. Parkinson, G., Alunite ore, through low-grade, can now be treated to yield alumina and fertilizers, Engineering and Mining Journal, June 1971, p. 108.
21. Parkinson, G., Golden pilot plant points way to 500,000 tpy alumina from alunite mine in Utah, Engineering and Mining Journal, Vol. 175, No. 8, Aug. 1974, p. 75.
22. Peters, F.A., and Johnson, Revised and updated cost estimates for producing alumina from domestic raw materials, Bureau of Mines Information Circular 8684. Government Printers, Washington, D.C., p. 72.
23. The Rocky Mountain News, Firms buy Soviet process, Jan. 22, 1976, Denver, Colorado, p. 72.
24. Stermole, F.J., Economic evaluation and investment decision methods, Investment Evaluation Corporation, Golden, Colorado, 1974.
25. Thompson, D.L., Alumina and by-products from Utah alunite--the aluemet project, AIME Technical Presentation given in the fall SME-AIME meeting, 1976.
26. U.S. Bureau of the Census, Statistical abstract of the United States, 1972 (92nd ed.), Washington, D.C., 1972.
27. Wall Street Journal, Talk of aluminum industry price boosts before mid-year grows as demand rises, Vol. XCIV, No. 74, April 15, 1976.
28. \_\_\_\_\_, Foreign supply fears spur search in industry for alternate materials, Vol. XCIV, No. 65, April 2, 1976, p. 1.