THE DETERMINATION OF THE CONDITIONS FOR THE RECOVERY OF CONCENTRATE FROM TITANIUM BEARING ORES

A Thesis Submitted to the
Graduate School of Natural and Applied Sciences of
Dokuz Eylül University
In Partial Fulfillment of the Requirements for
The Degree of Master of Science in Mining Engineering, Mineral Pocessing Program

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August, 1998
İZMİR

M. Sc THESIS EXAMINATION RESULT FORM

We certify that we have read this thesis and that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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ACKNOWLEDGEMENTS

I would like to express my gratitude to **Prof. Dr. Ali AKAR** for his kind supervision, valuable suggestions and discussing throughout this study. I also thank to **Assoc. Prof. Dr. Uğur KÖKTÜRK** and **Hatice YILMAZ** for their help during the x-ray spectrometry.

I also want to express my gratitude to **my family** for their help during the my education life.

I also thank to my colleagues mining engineers **Mr. Hüseyin DÜNYA**, **Mr. Hayri ÖZBERK**, **Mr. Orhan AKARSU**, **Mr. Ramazan BÜTÜNER** and industry engineer **Mr. Ali TALAY** for their help during the preparation and writing of this thesis.

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ABSTRACT

The aim of this research was the determination of the conditions for the recovery of concentrate from titanium bearing ores. Dependent on this study, high TiO_2 grade of feldspar from Aydın-Çine district and titanium bearing eclogite from Ödemiş-Kiraz district were investigated. Different techniques was used such as; Multi Gravity Separator (MGS)., Wet Tabling and flotation were tested in order to fulfil this.

On the other hand, after mentioning general information, potential of Turkey and World and, at presented used of titanium and feldspar product. Furthermore, It was presented determined the concentration parameters of two sample ore.

According to the results of experiments, the highest TiO_2 grade and recovery of titanium bearing eclogite ore are obtainable by means of wet magnetic separator with flotation and wet tabling. Furthermore, the best result for recovery of TiO_2 from feldspar ore is obtained by flotation method.

ÖZET

Bu çalışmanın amacı titanyum mineralleri içeren cevherlerden titanyumun zenginleştirilme olanaklarınınn araştırılmasıdır. Bu çalışmaya bağlı olarak, Aydın-Çine bölgesi yüksek TiO_2 tenörlü feldspatlar ve Ödemiş-Kiraz bölgesi rutilli eklojit cevherlerinin zenginleştirilmesi araştırılmıştır. Zenginleştirme işlemlerinde; MGS, Sallantılı Masa, Flotasyon yöntemleri egemen yöntem olarak seçilmiştir.

Ayrıca, genel bilgiler kapsamında Dünya ve Türkiye potansiyelleri, titanyum ve feldspat ürünlerinin kullanım alanları verilip zenginleştirme parametreleri saptanmıştır.

Yapılan deneylerde rutilli eklojitdeki en yüksek TiO_2 tenörüne, yaş manyetik separator kombinasyonlu flotasyon ve sallantılı masa deneyleri ile ulaşılabileceği, feldspat cevherindeki TiO_2 'nin zenginleştirilmesinde ise flotasyon ile en iyi sonucun alınabileceği tespit edilmiştir.

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CHAPTER ONE
INTRODUCTION

1.Introductıon

Titanium and Feldspar are two of the most important raw materials of industry. Titanium is used to manufacture titanium pigment, an ingredient used in surface coatings. Because of its high refractive index, white-useful for paper coatings. Another major use of titanium is aerospace industry. In addition to, Titanium is used in housing, construction, reading, clothing etc. Because of its versatile properties, titanium is a "quality of life" product and are mainly consumed in industrialized countries. On the other hand; feldspar is used glass, ceramics, paint and plastics industries, because of having specifications for demand. Our long range plans and commitment to industrial minerals, and specifically feldspar, will ensure our customers a comfortable future.

The most titanium deposits are found in Norway and South Africa, The major producers of titanium is Australia and South Africa. Somewhat, the possibility is examined of the exploitation of the eclogite deposits that have an high rutile contents and are rather common, but these deposits have low grade in order to recovery of economic. On the other hand, the largest feldspar deposits are found in the west of the Turkey, with the main mining operations being in the Aydın-Çine, and Muğla-Milas regions, located around the part Güllük. Most of the Turkish Feldspar produced is sodium-feldspar.

In this study, both high titanium grade of Aydın-Çine feldspar and Titanium eclogites concentration recovery parameters were investigated. In this first step, it was determined grindibility factors. Result of beneficiation studies are selected flotation system each of them.

Enrichment tests of titanium eclogite by multi gravity separator (MGS). In this stage it was aimed to recovery clean rutile product, and finally, rutile was taken 5.08 % grade of TiO_2 with 97.19 % recovery. Optimum condition of MGS was determined as follows;

Particle size	: -106μm
Rotation Speed	: 180 rpm
Water Supply	: 3.5 lt./min
Tilt	: 4°
Feed Rate	: 30kg./h.
Solid Concentration	: 30 % Solids

In this wet tabling tests of titanium eclogite it was aimed to recovery clean rutile product, and finally, rutile was taken 7.56 % grade of TiO_2 with 98.95 % recovery. Optimum condition of wet tabling was determined as follows;

Pulp Density	: 30 % Solids
Amplitude	: 10-25 mm
Tilt	: 1/48-1/24
Speed	: 240-325 strock /min.

Studies of titanium eclogite flotation was operated with three step. It was taken 4.10 % grade of TiO_2 with 37.44 % recovery. Typical practice is shown under the following operating conditions;

Pulp Density	: 25 % Solids
Particle Size	: -106μm (92.95 %)
Armact T	: 400 g/t
Dowfroth 1012	: 30 g/t
Fuel Oil + Burning Oil	: 400 g/t
Wet Magnetic Separator	: 5000 Gauss
pH	: 2.5-3 with H_2SO_4
Aero 801	: 300 g/t

Aero 825 : 600 g/t

Condition : 10 min.

Cleaner Flotation : All the amounts of reactives feed for cleaner used were half of basic flotation reactives.

Studies of feldspar flotation was operated with three step. After the microscopic examination the best conditions were given under the following operating parameters.

Pulp Density : 25 % Solids

Particle Size : -106μm (96.26 %)

Armact T : 450 g/t

Dowfroth 1012 : 25 g/t

Fuel Oil + Burning Oil : 400 g/t

pH : 2.5-3 with H_2SO_4

Aero 801 : 300 g/t

Aero 825 : 600 g/t

Condition : 10 min.

Cleaner Flotation : All the amounts of reactives feed for cleaner used were ½ of basic flotation reactives.

Finally, the highest TiO_2 grade and recovery are obtainable by means of flotation with wet magnetic separator and wet tabling. The grades reached after the combination with wet magnetic separator and flotation is 4.10 % TiO_2 with a recovery of 37.44 %. However, at wet tabling study, the grades reached 7.46 % TiO_2 with a recovery of 98.95 %.

CHAPTER TWO
GENERAL INFORMATION

2.1. General Information on Titanium

Titanium is the seventh most abundant metal (about 60% earth's crust), more plentiful than nearly all of the most common industrial metals accept aluminum and iron. However, it rarely occurs in concentrations rich enough to be suitable for ore. It is present in minor amounts in most rocks, and deposits of titaniferous magnetite are common but are seldom used because of the metallurgical difficulties in separating the iron and the titanium. (Riley1994,)General properties of titanium are given in table 2.1.

Table 2.1 General Properties of Titanium Minerals

	Rutile	Ilmenite
Color	Black, yellowish brown, red, reddish brown	Black, dark gray red, brownish gray
Hardness	6-6.5	6-6.5
Specific Gravity	4.18-4.25	4.17
Crystal System	Ditethragonal dipyramidal	Threegonal remboedrick
Chemical Formula	TiO_2	$FeOTiO_2$

Source: Endüstriyel Hammaddeler, Köktürk, U.(1992)

Elemental titanium has become famous as a space age metal. It has been known as an element for nearly two countries, but its wide-scale commercial adoption dates from more recent times, ferro alloys, 1906; titanium dioxide pigments, 1908; and titanium metal, 1948. It has enjoyed a good growth rate and many new mines have opened in recent years to meet this demand. (Aplan,1988)

2.2. General Information On Feldspar

Feldspars are common rock forming minerals, particularly in acidic igneous rocks which are alumina silicates with varying amounts of K, Na, and Ca; commercial feldspars, either Na or K rich, lie between end member composition. The term derives from the German name Feldspath common readily clearable mineral. There is no ambiguity about the name feldspar itself. This is a general term of a group of related minerals, which are silicates of aluminum, combined with sodium, potassium and calcium. The principle feldspar species are orthoclase or microline ($KAlSi_3O_8$), albite ($NaAlSi_3O_8$) and anorthite ($CaO.Al_2O_3.2SiO_2$). (Rau,1986; Harben,1992; Kuzwart,1984).

The feldspar are the most abundant minerals of the igneous rocks and since the rocks make up largest proportion of the earth's crust by volume the feldspars are the most abundant minerals of all. The general properties of the feldspars are given in Table2.2.

Table 2.2 General Properties of Feldspar

Color	White, fair pink, yellowish, yellowish green, colorless
Hardness	6
Specific Gravity	2.5-2.8
Melting Temperature	1100-1580 °C
Chemical Formula	WZ4 O8 W: Na, K, Ca, Ba, Z: Si, Al (S /Al 3/1 or 1)

Source: Industrial Mineral HandyBook (Harben,1992).

Feldspars-valued for their content of alkalis when heated to 1100-1400 °C dissolve all components of ceramic substance-quartz and washed kaolin; the solidify to form milky white glass-a sintered ceramic ceramic ware (porcelain) or porous ware(faience). The content in feldspar imparts strength to the ceramic ware after firing as the aciculate mullite. Al_2O_3, $2SiO_2$ forms at 900 to 1000 °C (. Kuzvart,1984). Typical commercial analyses of feldspathic minerals are given in table 2.3.

Table 2.3 Typical commercial analyses of feldspathic minerals (Harben,1992)

	Soda feldspar	Potash feldspar	Low-iron aplite	Nepheline syenit	Calumite
SiO_2	67.54	67.04	63.71	61.4	38.80
Al_2O_3	19.25	18.02	21.89	22.74	10.50
Fe_2O_3	0.06	0.04	0.09	0.06	0.30
CaO	1.94	0.38	0.48	0.70	38.50
MgO	trace	trace	trace	trace	1.40
K_2O	4.05	12.10	2.37	4.95	0.50
Na_2O	6.96	2.12	5.60	9.54	0.40

2.3. Petrographic Properties of Titanium

Titanium is the seventh most abundant element of the Lithosphere, there are only a few minerals in which it occurs in major amounts: rutile, anatase, and brookite, ilmenite and its alteration products, including leucoxene, perovskite ($CaTiO_3$), and sphene ($CaTiSiO_3$). Anatase may be emerging as a significant ore mineral of the future, but ilmenite, leucoxene, and rutile have been the large volume ore. Titanium is found in more than 45 different minerals but most commonly occurs as titanomagnetite, ilmenite and rutile. Titanomagnetite normally contains less than 10 % TiO_2 making it of little or no value as an ore of titanium. (Langtry,Stanley,1988)

İlmenite: The chemical formula of theoretically pure ilmenite is $FeO.TiO_2$. It was that up to 6% Fe_2O_3 may be dissolved in solid solution series exist between ilmenite and hematite. Ilmenite($FeTiO_3$) forms an incomplete series with geikelite ($MgTiO_3$) and pyrophanite ($MnTiO_3$). Ilmenite and its alteration products are the most abundant TiO_2 sources on Earth. There are a number of types of ilmenite mined for TiO_2. The first of hard rock deposits associated with gabbros, diorites and anorthosites. They

TiO_2 sources on Earth. There are a number of types of ilmenite mined for TiO_2. The first of hard rock deposits associated with gabbros, diorites and anorthosites. They are primarily in producing TiO_2 slag. Fresh, Unaltered ilmeinte is black with a metallic to submetallic luster.

Ilmenite alters very slowly from crystalline $FeTiO_3$ to an amorphous mixture of FeO, Fe_2O_3. During this process some of the iron oxides are leached out of the grains thereby upgrading the TiO_2 content. The end product of this alteration is either rutile or anatase. Fresh unaltered ilmenite is soluble H_2SO_4 and HCI, but as alteration progresses, its solubility decreases. Its and products an acids.

Rutile: Rutile, the high pressure, high temperature polymorph of TiO_2, is the commonest from in nature and is a widespread accessory mineral in high grade metamorphic gneisses and schist and in igneous rocks. Rutile used in titanium commerce today is in two forms: primary rutile, that makes up the major portion, and secondary rutile. Secondary rutile is found in beach sand deposits and is the end product of the ilmenite alteration process. Other titanium minerals (anatase, leucoxene, and perhaps titanite and perowskite)could also play a role in the future. (Langtry, Stanley 1988).

Leucoxene (Pseudorutile); The mineral has become by an ilmenite alteration. The colors can be enhanced for accurate identification by heating to 1000 ^oC for ten minutes in an oxidizing atmosphere. At this stage of alteration, the TiO_2 content of the altered grains has increased to 80 to 90 percent; they are only partially soluble in acids, and are only slightly paramagnetic. Anatase; Although anatase occurs in nature as on of three polymorphs of TiO_2, It also commonly occurs as the and product of ilmenite alteration process in beach sands.

Perovskite; Perovskite deposits have been of interest as titanium ores for a number of years . Work by the USBM (United States Bureau of Mines) in 1973 resulted in the production of a chlorinatable. Product from titanium carbide made on a laboratory scale by smelting perovskite with carbon. More recently USBM. Announced that they had successfully produced TiO_2 pigment from perovskite using an acid sulfating method. Others; Other common but little known titanium minerals are; Pseudobrookite (altered ilmenite about 1400 °C pigment), and sphene also called titanite.($CaTiSiO_5$).(D.D Carr,1986).

The most common titanium mineral (ilmenite) obtained from both rock and sand deposits. Another source is titaniferous magnetite, when both iron and titanium values can be recovered. Since natural rutile is produced only from sand deposits, that are unlikely to satisfy so a huge demand as could be anticipated if ilmenite had to be fully replaced by rutile, titanium industry is paying an increasing attention to the "alternative sources " of rutile.

Small, high grade rock deposits of rutile have been worked in the past, whilst big, low grade deposits, the only type of deposits suited to modern mass- production mining, have been disregarded. Something, however, is changing: A big anatase mine is under development in Brazil, rutile-zirkon deposits investigated in France, rutile deposits in eclogite rock are tested in C.I.S., etc.(Mancini,Martinotti,1979)

Only mining problems will be dealt with in detail; beneficiation is the subject of a parallel investigation program, whose fist results, however, will be also exposed, to conclude a preliminary analysis of the technical and economical feasibility of the project.

- **Ilmenite, from sand deposits:** Australia, USA, Malaysia, Sri Lanka, India, S.Africa;
- **Ilmenite, from rock deposits:** Norway ,Finland, USA;
- **Rutile (all from sand deposits):** Australia;
- **Titaniferous slags and synthetic rutile:** Canada, S. Africa.

Ilmenite reserves (both in sand and in rock) can be assumed to be unlimited; rutile reserves in sand deposits, if only proved mineral unlimited; rutile reserves in sand deposits, if only proved mineral is taken in account, do not exceed 15 Mt of recoverable mineral.

Biggest known rutile reserves in sands are in Australia and in Sierra Leone, European ilmenite came almost exclusively from two large production areas (in Norway and in Finland), where great rock deposits are exploited. Also low great ore is presently mined, due to cost reductions allowed by large size production units. Europe has no rutile mines, and European TiO_2 industry is mostly ilmenite-based. A change to rutile-based production systems(than could solve some heavy pollution problems) could only resort on importation of the raw material from other geographic areas, or on "alternative rutile sources".(Mancini ,Martinotti,1979)

2.3.1 General description of the eclogite deposits

Eclogites are metamorphic rocks, with pyroxene and garnet as the most abundant materials, a number of other minerals can be associated with them, giving rise to "hybrid eclogites" as "glaucophane eclogistes", "hornblende eclogites" etc. Pyroxene is usually as sodium rich term of the "omphacite" family; garnet is usually a pyrope-grossularia-almandin admixture.

Rutile is an important accessory mineral in eclogites, and usually ranges between 0.5-2.0%

The more widely recognized classification systems of eclogites, are based on associations, as follows:

- **Eclogites associated with kimberlites, dunites and peridotites:** May contain diamond as an accessory mineral, garnet is pyrope-rich. Better known occurrences are in S. Africa and Siberia.
- **Eclogites associated with high temperature and high or medium pressure metamorphic complexes:** As accessory minerals may contain brown hornblende and cyanite. In Europe are found in Scandinavia and Carpathians.
- **Eclogites associated with high pressure, low temperature metamorphic complexes ("blue-schists"):** The most common eclogites belong to that class and are widespread in metamorphic complexes of alpine age. Have been found in the

Small serpentine scales can be found in the eclogite, accounting for less than 15% of the orebody mass; conversely small masses of eclogite are enclosed in the surrounding serpentines.

Qualitative mineralogic composition is rather uniform, whilst quantitative composition may vary noticeably. A sort minerologic description runs as follows:

- Proxene, of the omphacite type, is the most abundant mineral
- Garnet, 25-30% by weight, is a mixture of grossularia, pyrope, almandine; garnet crystals are often large (1mm or more)
- Amphiboles, when present, are of the sodium bearing types (glauco-phane), and of the actinolyte family. Amphibole crystals usually prove to be more recently grown than pyroxenes and garnets
- Epidotes, white mica, albite, titanite, quartz, pyrite, ilmenite, calcopyrite, apatite are minor components.
- Rutile, an accessory mineral that is always present in the rock, is sometimes associated with ilmenite.

Table 2.4 Chemical composition data of titanium eclogite (Mancini, Martinotti,1979).

SiO_2	42-44 %	**CaO**	8-10 %	**V_2O_5**	0.1-0.5 %
Al_2O_3	10-12 %	**Na_2O**	3-5 %	**Zn**	0.1 %
Fe_2O_3	4-6 %	**K_2O**	0.05-0.2 %	**Pb**	10 ppm
FeO	13-15 %	**P_2O_5**	0.05-0.5 %	**Co**	50-100 ppm
MnO	0.2-0.5 %	**Cu**	10-200 ppm	**TiO_2**	2-10 %
MgO	5-7 %	**Ni**	10-200 ppm	**Cr**	300-500 ppm

2.3.2 Ore benefication

A separate experimental study, whose results are shortly summarized in this study, has been carried on the benefication problems of the rutile bearing eclogite.

Eclogite treatment difficulties arise: a) From the same factors already discussed (rock toughness and abrasivity); **b)** From the fine dissemination of the valuable mineral; **c)** From the mineralogical complexity of the rock.

Separation cycle is undoubtedly complex, because of the overlap of many physical properties of the rutile and of the gangues; gravity separation proved to be usuless: Rutile specific gravity (4-4,2) is close to average rock's specific gravity (3,5 g/cm^3) and attempts failed even to separate the pyroxene fraction . On the contrary, magnetic separation proved to be useful, being in average the rutile much less susceptive than ilmenite and garnet; also pyroxenes can be to a some extend separated from rutile with high intensity magnetic separators.

Furthermore, flotation reagents showing an appreciable selectivity between rutile and silicates heve been found and tested in a small scale continuous plant. Rutile-pyroxene separation by flotation.(Mancini, Martinotti, 1979)

2.4. Petrografic Properties of Feldspar

Feldspars the most abundant minerals of the igneous rocks, occur in numerous forms and mixtures. The feldspars are important rock-forming minerals and constitute nearly 60% of many igneous rocks. The most widespread type of such rocks from which commercial feldspar can be produced is that called “pegmatite”.

Feldspar from granted and alkaline intrusive rocks is used more and more instead of pegmatite feldspar. Pegmatite is prevalent, widely distributed; generally coarse-grained igneous rock from which are obtained predominantly potash feldspar and a certain number of other economic minerals. Pegmatite are dikes and bodies of irregular shape and of a size measured in feet or yards in most cases, rather than in miles. Many of them contain crystals of various minerals; including the feldspars, that are much larger than are found in the host rock, the granite. There are large masses of feldspar that are sufficiently free from iron-bearing silicates so that products acceptable to the ceramic industry can be produced in some cases simply by hand sorting. Most of this feldspar in pegmatite, however, does contain intergrown quartz up to 25 percent. (Castle,1986).

Some other rocks rich in feldspar and low in iron minerals have been quarried for the production of commercial feldspar and it is in the naming and defining these other rocks that the greatest divergence in use terms has accrued between scientific and practical writing. There is a rock near Piney river, Virginia, that is worked for feldspar. The commercial producer of feldspar call this rock and “applite” in which both titanium and feldspar are present.

Applite is a feldspathic rock mined and beneficiated in one location that both titanium and feldspar minerals are present. A dike rock consisting almost entirely of light colored mineral constitutes and having a characteristic fine granatic texture, but when the term is used with no modifier it is understood to be granatic, consisting essentially of quartz and orthoclase.

Alaskite is another term requiring understanding if not precise use. A distinctive rock type customarily called by this name is found near Spruce Pine. It is a plutonic rock consisting of orthoclase, microline and subordinate quartz, with few or mafic constitutes. Plagioclase may or may not be present. In the feldspar trade, the term defines specially a granite mass found in the area of Sprute, Pine, North Caroline from which the feldspar is produced.(Carroll,Rogers,Phılıp,Kefton,Teague,1988)

The alaskite is composed, rouglyof the following principal mineral ingredients; Plagioclase 45%, quartz 25%, microline 20%, muscovite 10%.

In the recent years, the feldspar industry has been using nepheline syenites to supplement feldspar because of the higher alumina and lower slica of these rocks as composed with feldspar. The feldspar nepheline belongs to be feldspathoid group, differing form the feldspars in having less slice in the molecule than to be feldspars. Nepheline syenites are members of the large group of igneous rock called the"alkeline rocks" because of their high soda and potash content as compare with the granatic rocks.

Deposits of feldspar in granite pegmatite are the oldest industrial type of this raw material, because the large dimensions of feldspar crystals made hand sorting possible. Granites are extremely abundant, a certain number of them being good sources of high quality feldspar. Granite is course-grained acid plutonic igneous rock. Quartz generally makes up 25 to30 percent of the rock; feldspar is the other major component. There is a wide range of minor constituents, among them muscovite, biotite, aphatite, zircon, allanite, hornblende, magnetite zoisite epidote and garnet. The feldspar component of granite is principally of the alkali members, so potassium and sodium feldspar are being in some ratio. The remaining feldspar is of the plagioclase series.

Various beach and river sands containing economic amounts of feldspar have apparently acquired the feldspar principally from granatic bodies and possibly also from feldspathic metamorphic rocks. Basis for the statement is in the assay of feldspar concentrates from these sands. Normal decomposition of feldspar involves first the breakdown and kaolinization of Na-spar, leaving behind a component higher in K-spar. Thus, if an assay is run on spar concentrate from feldspathic sand and the K_2O is high, that would indicate either extreme decomposition or that the feldspar originated in a pegmatite. Most concentrates usually do not assay over 7 percent K_2O: considerably below usual pegmatite feldspar, and much more typical of feldspar from partially weathered granite. (Carroll,et al,1988)

Table 2.5 Feldspathic Minerals

Minerals	Formula	Color/Luster	SG	H	Crystal system/habit	Occurrences
Albite: Latin albus = white, for its color	$NaAlSi_3O_8$ 11.8%Na_2O 19.4%Al2O3 68.8% SiO_2	Colorless to white to white-gray; transparent to subtranslucent; vitreous to pearly	2.6-2.62	6-6$^{1/2}$	Triclinic; tabular,massive, granular	Acid and intermediate igneous racks; Pegmatite ;granite, andesite, syenites, other alkaline igneous racks; gneiss, crystalline schist, granular limestone& marble
Anorthite: Greek for not straight , for its triclinic	$CaAl_2Si_2O8$ 36.6%Al2O3 43.3% SiO_2	Colorless, white, gray,reddish;transparent to translucent; vitreous	2.74-2.76	6-6$^{1/2}$	Monoclinic;short prismatic, blocky	Basic plutonic and volcanic rocks-gabbros, calc-silicate hornfelses, anorthosite, norite, and lavas
Microcline: Greek micro little and cleaning = to incline due to its variation of cleavage angle from 90°	$KAlSi_3O8$ 6.9%K_2O 18.3%Al2O3 64.8% SiO_2	White,gray-white,gray,pinkish; transparent to translucent vitreous	2.56	6-6$^{1/2}$	Triclinic short prismatic, blocky, massive, granular	Acid igneous rocks like pegmatite, granite, syenite, crystalline schists, contact zones, hydrothermal veins
Orthoclase: Greek for straight and klasis = fracture due to its 90° cleavage angle	$KAlSi_3O_8$ 16.9%K_2O 18.3%Al2O3 64.8% SiO_2	Colorless, white, gray, yellow, reddish , greenish ; transparent to translucent; vitreous to pearly	2.55	6-6$^{1/2}$	Monoclinic;short prismatic,blocky, massive or granular	Acid igneous rocks like granite, felsite, syenites, rhyolites, and trachytes, in large xls in pegmatites, in ore veins, feldspathic sandstones and arkosic sedimanter rocks, metamorphic rocks

Source: various including (Roberts et al. , 1990).

CHAPTER THREE
POTENTIAL

3.1 World Titanium Reserves and Production

Total US ore serves in 1990 were 8.1 Mio. tons of TiO_2 with an additional 34.7 Mio tons as a reserve base. As newly discovered deposits in the US and other countries are developed, it appears that there will be sufficient TiO_2 reserves to last 20 to 30 years at current world production levels.(Garnar,1994.) World titanium reserves are given in figure 3.1.

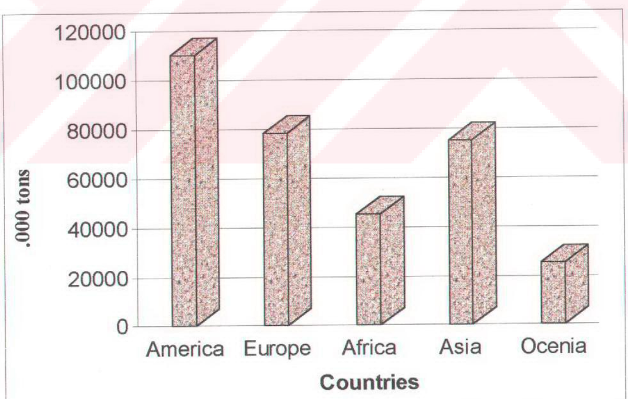

Figure 3.1 World titanium reserves. (US Bureau of Mines, 1990)

Owing to statics world titanium production increased last decade, especially, pigment manufacturer's demand caused to increase of production. Titanium production are given in figure3.2. and ilmenite production are given in figure 3.3.(Skillen ,1996)

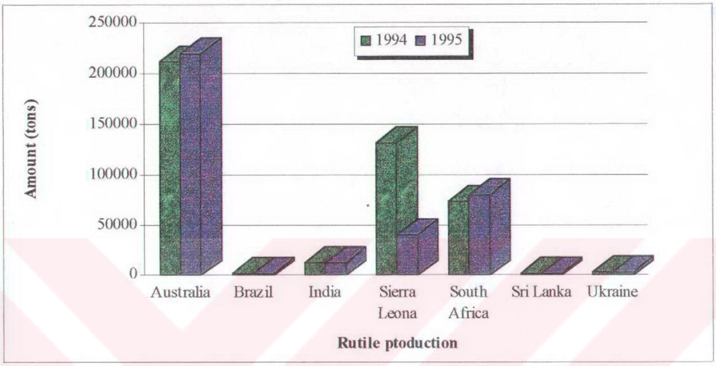

Figure 3.2 Rutile production. (Skillen,1996).

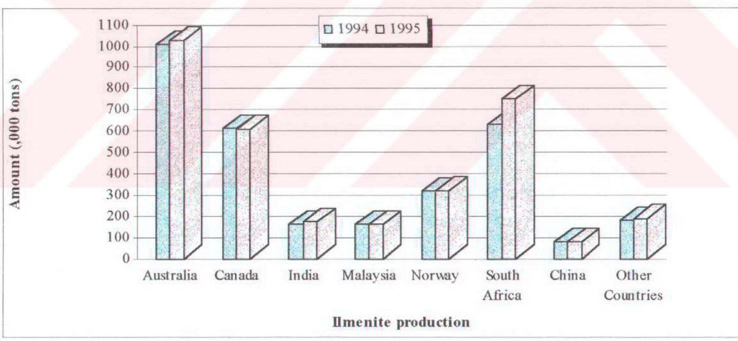

Figure 3.3 Ilmenite production. (Skillen,1996).

3.1.1 America

Three companies currently produce titanium minerals in the USA, Namely P.W. Gillibrand Co. in California, and E.I. Du Pont de Nemours & Co. Inc. and RGC Mineral Sands (USA) Which are both situated in Florida. These companies have completed a number of pilot plants, pre-feasibility, environmental and engineering studies.

The company is producing material at the rare approximately 25.000 tpa. A typical composition for oak Springs alluvial concentrate is TiO_2 (48.5 %),(FeO 38 %),(CaO 1.2%), MgO (0.8%), Al_2O_3 (0.5%) and SiO_2 (2.2 %).The company has executes a 500 ton bulk sampling programmed, pilot milling operations and bench scale TiO_2 concentration trials that have yielded a concentrate containing 50-55 % TiO_2. Its economic studies with a full feasibility study, that will include pilot plant and engineering design work. The company will subsequently begin the permitting process, the operation, which will include a 100.000 tpa sulphation plant. However, with a combined ilmenite production from all mines of under 118.000 tons for 1994. (Skillen, 1992)

Du Pont dredges ore from two mines in swampy surroundings, located at Highland Trail Ridge and Starke Trail Ridge, with all processing carried out at a paint cited at the latter. The ore is composed of the traditional suite of minerals, including ilmenite, rutile, leucoxene, and zircon. Du Pont will have raised its production capacity to 300.000 tpa of titanium ore with reserves forecast to last until 2010. .(Skillen, 1996)

3.1.2 Brazil

Brazilian minerals sands deposits are primarily located in the coastal area of Paraiba state and amount to approximately 4 m. tons of ilmenite (54-57 % TiO_2) and rutile (95-97%TiO_2). In addition, smaller reserves are situated in the Prado/Cumuruxatiba are of Bahia, the Aracruz and Guarapri regions of Espirito Santo and the Sapucai river region of Minas Gerais.

The country has two major companies directly involved in the production of heavy mineral concentrate. "Nuclemon Minero Quimica Ltda" and "Rutilo é Ilmenita do Brasil SA (RIB)". Nuclemon operates mines and on site concentrators which exploit ilmenite/zircon deposits at Sao Joao da Barra, Boa Vista and Barra do

Itabapoana as well as Rio de Janeiro. Esprito Santo and Bahia as well as two physical separation facilities at Sao Paula. In addition, 1990 the mines performed well within their combined 540.000 tpa capacity, as mining totaled 333.000 tons of crude ore, the titaniferrous components of which amounted to 11.000 tons of ilmenite and 110 tons rutile. (Skillen,1992)

3.1.3 Norway

Norway is abundant in ilmenite and rutile resources, which are predominantly found in hardrock deposits. One Norway titanium deposit is mined; the company Titania A/S exploits an ilmenite hardrock deposit (Tellness deposit) in Hauge, about 90 km southeast of Stavanger.

The company's mine is situated in Sokndal in the southern part of Rogaland County, near to the border with West Agder county in southern Norway. Company's processing plant has a capacity of 850.000 tpa, of which 350.000 tons is made available to Tinfos Titan & Iron KS for slag production.

A typical analysis of Titania ilmenite is TiO_2 (44–45%), SiO_2(2–3.5%) FeO (34.5 –35.5%), Fe_2O_3 (12 –13%), MgO (3.5 –5.1%), V_2O_5 (0.15-0.2%), Cr_2O_3 (Less than 0.08%) and P_2O_5 (Less than 0.03%). Norway plays host to the world's one other titanium slag producer.(Skillen, 1996)

3.1.4 Vietnam

Vietnam has certainly been a mixed bag when it comes to overseas involvement. As the sun sets on a disgruntled Westralian Sands, whose involvement in the Austin. However, has progressed without interruption and is scheduled for imminent production.

Vietnam has been producing low quality ilmenite for some time, but due to lack of foreign investment. Technology has not kept pace with deposit recovery, and the relatively poor material is consequently snapped up at low price by the Japanese. Vietnam is unfortunate to find itself embroiled in an embargo situation with the USA; a legacy of the war between the two countries in the late sixties, and this serves to discourage other potential sources of overseas revenue who do not whish to upset the status quo by pumping money into the country.(Skillen,1992).

3.1.5 Japan

"Ishihara Sangyo Kaisha Ltd." (ISK) operates the only synthetic rutile plant on the islands, which, at present, produces around 57.000 tpa , 20.000 tons of which is destined for a chloride facility in Singapore, the remainder supplies the only chlorite route plant in Japan, also owned by ISK. Feedstock for synthetic rutile production predominantly originates from ISK`s wholly owned Australian subsidiary, and is supplemented by material from Westralian Sands, in which the Japanese company holds a minor interest. (Skillen, 1992).

3.1.6 Australia

Australia is often regarded as the home of mineral sands, and there is certainly nowhere else in the world that has such a developed and integrated industry. However, recently, new green field projects have been conspicuous by their absence, and were one of the strongest indicators of the suppressed state of the international titaniferous feedstock market. Australia has always dominated world mineral sands production , and has been at the fore front or processing innovation and exploration activity within the sector for many years. However, the continuing depression ailing market place have forced producers to bide their time and wait for the corner to be torned ,a corner which, at present, has yet come into view.

In 1991, Australian production amounted to approximately 22.000 tons of leucoxene, 190.000 tons of rutile, 283.000 tons of zircon, which has lowest figure for nearly two decades, and 1.5 m. tons of ilmenite. Traditionally, companies have been categorizedinto either west coast or east coast producer and until the recent closure of Woodburn Mineral Sands in New South Wales , were evenly split between either shoreline, with each coast supporting producers.

The other additions to capacity coming on line in Australia are both in the hands of established producers, and involve the addition of extra synthetic rutile capacity through either debottlenecking or the construction of an extra production line. The former is in the hands of "Twiest Joint Venture" , which operates a plant at Muchea, Western Australia. Capacity is currently around 168.000 tpa , although this debottlenecking exercise will serve to provide a further 40.000 tpa by either the end of this year, or early 1997.(Skillen, 1992).

3.1.7 Canada

Following the completion of a prefeasibility study in 1994, which demonstrated the potential economic viability of the Natashquan mineral sands project, a number of programmers were undertaken by "Tiomin Resources Inc." during 1995 with the intention of completing a bankable feasibility study for an integrated project. This would comprise a mine at Natashquan together with secondary processing plants to upgrade the ilmenite to 100.000 tpa of synrutile and hot briquettes iron.(Skillen, 1996).

A 20 year mine plan is scheduled to be completed by the end of this year, at which time the company may be in a position to decide whether or to proceed with the project. The company currently mines around 3 m. tpa of material from what is one of the world's only two operational hard rock deposits with reserves of 120 m. tons of slag for 1993.

Although the slag reports a guaranteed figure of 75 % TiO_2, It is the impurities that effectively determine the fate of the finished slag. In this regard, despite relatively low amounts of vanadium and chrome meaning that it would be suited to both sulfate and chlorine route processing, the limiting factor is its high magnesium content, which with a typical assay around 5 %, prevents the slag from being applied in the chloride market. (Skillen,1992).

3.1.8 Malaysia

Malaysian mineral sands are very much the sleeping partner in a relationship with the country's tin producers, with the overwhelming majority of heavy minerals tied up in the island's tin-bearing cassiterite deposits, and enjoying nothing more than by-product status. The major problem, therefore, is that when the supposedly active member of the partnership opts to slumber, peacefully, there is virtually nothing that the other party can achieve. As everyone is aware, the tin price has declined dramatically in recent years, with the resultant falling away in mining activity having an adverse effect on sands output.(Skillen,1992).

Synthetic rutile production in Malaysia is centered on one operation, controlled by "Hitox Corp. of America" through its subsidiary "Malaysian Titanium Corporation". The TiO_2 grade ilmenite used as feedstock, originates from a highly weathered deposits, grading 60 % titanium dioxide, differs from high grade material by having a lower iron content and a higher percentage of TiO_2.(Skillen,1996).

3.1.9 India

India is fortunate enough to be blessed with a trove of heavy mineral riches, situated along both the east and west coasts of the peninsula. At present, the materials are exploited by two major companies, namely "Indian Rare Earth's Ltd." and state-owned "Kerala Minerals and Metals Ltd." Of these two, it is the former, owned by the federal government under the auspices of the Department of Atomic Energy, that is more significant in terms of production and exports.(Skillen,1992).

Indian Rare Earth's dominates mineral sands production in the republic and possesses a synthetic rutile facility at Charaptur in the Ganjam district of Orissa. The plant production capacity is around 100.000 tpa of synthetic rutile. State-owned Kerala still operates a plant at Chavara in the Kerala district with and operational capacity of approximately 22.000 tpa.

Other main synthetic rutile producers; "Dhranghdra Chemical Works Ltd.", which is situated at Sauparam, Tamil Nadu, has 12.000 tpa synthetic rutile production capacity. "Cochin Minerals and rutil Ltd.", which is planning to commence trial production. The plant which is situated at Edayar, Kerala, is expected to provide 10.000 tpa synthetic rutile.(Skillen, 1996).

3.1.10 South Africa

One of the most likely new projects to come into operation will be by South Africa still major "Iscor Ltd." The company became active in mineral sands marked when it acquired the exploration leases of shell of South Africa and "Rhombus Mining "in 1994 which provide access to reserves in the former Transkei as well as in the Natal/Kwazulu area near to Richards Bay. (Skillen, 1996).

The eventual plan is to construct a 200.000 tpa smelter with a service life of 20 years, and the current intention to get this in operation by 1999. As well as slag production, zircon will also be a consideration, and Iscor calculates that at the mining rate, production would be 34.000 tpa in Transkei and 50.000 tpa in Natal. Surface mining would then be expected to start in 1998. Natal would also have the added benefit of being able to supply 100.000 tpa of pig iron, 29.000 tpa of rutile and 1.3000 tpa of leucexene at full production. (Skillen,1992).

3.1.11 Mozambique

Eire based company, Kenmare Resources, first identified the deposit in Mozambique several years ago, and the feasibility study is now well in progress. The orebody has been identified as having 167 m. tons of proven reserves with a head grade of 3.25 % heavy minerals, and the company anticipates that a mining rate of 18m. tpa will yield a total of 418.000 tpa of ilmenite, split between sulphate and standard grades, 8.000 tpa of premium grade rutile and 35.000 tpa of zircon. The specifications for the titaniferous components of this production are giving in the accompanying table.(Skillen, 1996)

.In spite of negative decision regarding the expansion of mining activities at Richards Bay Minerals, in which Gencor Ltd. holds a 50% interest, the mining house maintains a strong intention to expand its mineral sands portfolio, with the announcement that it is evaluating a mineral sands resource in the northern part of Mozambique.

With an eye to producing a high grade feedstock, Gencor anticipates that it will ship around 900.000 tpa of concentrate from the mining site at Moebase to a smelter. The final decision on site selection will depend upon an assessment of political risk, the coast of electrical power and the quality of infrastructure.(Skillen,1992).

3.1.12 Sri Lanka

Ceylon Mineral Sands Corp.(CMSC), which commenced operations in 1957, continues to dominate Sri Lanka heavy minerals production with a mine and processing at Pulmoddai, 35 km north of the port of Trincomalee. The deposits, about 400 m from the coast, extend 8 km southwards from Arisimalia and possess a heavy mineral content of 60-70 %.

The plant, which is fully integrated into the mine complex, is designed to produce a total of 200.000 tpa ilmenite, 10.000 tpa rutile and 8.000 tpa of zircon when fully operational (Skillen,1992).

3.1.13 Thailand

The company currently sells all of its products within the country itself, with the rutile and leucoxene both utilized in welding rod manufacture. However, as industry is generally experiencing a time of meagre fortunes. Sakorn anticipates cutting its production even further in the near future.

Scorn Minerals Co. Ltd. are the country's only specialist contributor to the global mineral sands market, operating a mine and processing plant in the Prajuab province producing ilmenite, rutile, with a guaranteed analysis of 95% TiO_2 leucoxene, with a guarented analysis of 90% TiO_2, and zircon, as well as a selection of associates minerals such as xenotime, monazite and columbite/tantalite. The operational capacity and projected output for 1992, with regards to titanium minerals is given in the accompanying table, and provides clear evidence of the struggle faced by many smaller scale produces in the current economic climate.(Skillen,1992).

3.2 World Feldspar Reserves, Production and Consumption

Feldspar is one of the most plentiful minerals in the earth's crust, is found in significant amounts in some sedimentary strata and in nearly all igneous formations. Presumptively workable deposits of feldspar are widely distributed throughout most of the world and the total quantity of the mineral potentially available is extreme large. Feldspar mineral could be extracted from the world's granite, a source that is virtually limitless.(Kuzvart,1984;Rogers,1985).

Worldwide reserves amounting to at least 1 billion tons can be assumed with no less conservatism. The actual quantities that exist as identified, hypothetical and speculative resources must certainly exceed any such figures by many orders of magnitude. World feldspar reserves shows in figure 3.4. Figure 3.5. shows domestic feldspar production between 1982-1994

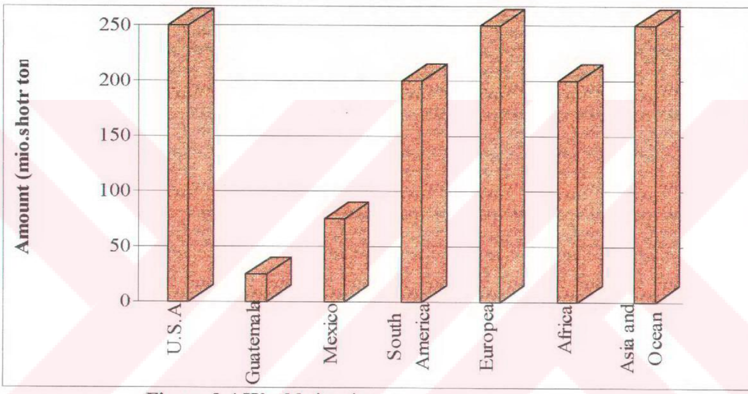

Figure 3.4 World titanium reserves.
Source: Industrial Minerals Yearbook& Mineral Fact and Problem.

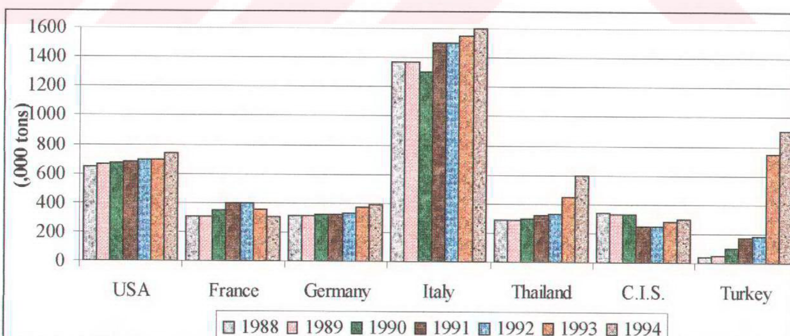

Figure 3.5 Feldspar production, 1988 throught 1994

3.2.1 U.S.A.

The U.S.A. is the world' s third largest feldspar producer with around 740.000 tpa producing in 1994, this figure being slightly down on the previous year. There are several feldspar-rich regions in the New England. The largest and most important is a belt of feldspar-rich pegmatite's that runs Appalachian Piedmont from Virginia to Alabama. (Bolger,1995)

The bulk of the 765.000 tons/year of feldspar produced in the united States comes from North Carolina and Georgia, aplite from Virginia, and feldspar-silica mixtures from South Carolina . Oklahoma. Virtually all this production is consumed domestically, and is supplemented with over 300.000 tons/year of nepheline syenite imported Ontario, Canada. .(Andrews,Pearse,Burt, 1988)

Feldspar is mined commercially in six states, with around 60 % of the national output being produced within the state North Carolina. The main domestic market for use produced feldspar within approximately 65 % going to the manufacture of glass, and 35 % for ceramics and other uses. The majority of the national feldspar output is produced by the for largest producers. Feldspar Corp., Kentucky-Tennese Feldspar Corporation (K.T.F.C.),U.S. Slica Co. and Minerals Corp. (Bolger,1995)

3.2.2 Canada

Feldspar production in Canada is dwarfed by the nepheline syenite industry, although Canada possesses abundant feldspar resources, with an estimated 100 m. topless of reserves in British Columbia alone. In 1995, around 50.000 tons of feldspar product is expected to be obtained, using magnetic separation, and it is anticipated that output will increase over the following years. The product will be a mixed sodic / potash feldspar for use in the manufacture of tiles and sanitaryware, and will be targeted at the European market. (Bolger,1995)

One company, which is currently moving into Canadian feldspar industry,is Canspar Resources Inc., a public company, whose feldspar deposits 150 miles east of Sept- lles is currently the final phase of development. There was no production from the operation during 1994, although bulk sampling was carried out. In 1995, around

50.000 tons of feldspar product is expected to be obtained, using magnetic separation, and it is aimed that output will increase over the following years. (Bolger,1990)

3.2.3 Brazil

Brazil's feldspar production for 1994 at 140.000 tons. The first in a planned series of privations of government- owned companies was completed at the and of 1993 when Coming (formerly Metaming), the mineral exploration company owned by the Minas Gereis state government, leased its Governador de Valadares feldspar plant to "Prominer Mineraçao" , as a 20 year contract, with a five yearly revision clause. Annual production of around 48.000 tons is believed to be used mainly by the glass industry and in lower grade ceramics, such as bathroom fittings.(Bolger,1995)

Nepheline syenite production from the deposit would be aimed at European, North American and domestic markets. Current Brazilian consumption is around 150.000 tpa of feldspar, a figure which looks set to rise if the present optimistic economic outlook persists. There has so far been interest from both Brazilian and Italian companies and Italian companies and the project is to be opened to public tender within the next few months.(Bolger,1997)

3.2.4.Scandinavia and Finland

The Fenno-Scandinavian Shield is rich in pegmatite, which are the source of the region's impressive feldspar production. The pegmatite has a typical composition of 29 % potash feldspar (85 % orthoclase and 15 % albite), 40 % soda feldspar (87 % albite and 13 anorthite),28 %quartz, and 2-4 % other minerals. The mine has an annual output of approximately 25.000 tons of potash feldspar and 45.000 tons of sodium feldspar plus quartz (30 %).

The area of western Finland is characterized by mica schist an gneiss, diorite hornblendite, and gabro. The only major feldspar producer in Finland is "Partek Industrial Minerals", formerly Lohja corporation. The company is a wholly-owned subsidary of "Pratek Corp". Partek has feldspar mines and processing plants at Kimito and Alavus in the south- west of Finland. Total production capacity for 1995 is expected to be 70.000 tpa. The products is exported to Europe, the far and Australia. (Bolger,1995)

3.2.5 Mexico

One of the major producers in Mexico is Materias Primas Minerales San Jose SA operates a 70.000 tons/year potassium feldspar mine at San Jose de Iturbide. This is a based on a Miocene crystalline tuff containing 40-45 % quartz and potassium feldspar. The ore also contains 0.5 to 1 % montmorrillonite and heavy minerals. A sister company , Materias Primas Minerales de Ahuazotepec SA, mines feldspar in the Pueblo district (Bolger,1995)

3.2.6.Germany

Germany is second only to the United States as a producer of feldspathic minerals. The main center of production is in the Bavaria, some 70 km east of Nürnberg. Total feldspar production capacity is around 150.000 tons and this is expected to rise to 160-165.000 tons in 1995. (Bolger,1995)

The leading producer of feldspar in Germany is Amaberger Kaolinwerke Eduard Kick GmbH (AKW). AKW's products are Feldspar sand 800 S, Feldspar sand 900 S (for glasses), Feldspar sand 900SF, Glazing feldspar 0305 (for ceramics).AKW's most important customers are manufactures on TV and container glass and producer of porcelain and sanitaryware major producers of feldspar is given in table3.1. (Bolger,1995)

Table 3.1 Main Feldspar Producer of Germany (Bolger ,1995)

Company	Region	Products	Capacity
Vilely& Botch AG	Turkismühle in Saarland	Na/Kfeldspar K- Feldspar	60.000 tons
AKW	Hirschau/Nürnberg	Na/K-Feldspar and Feldspathic sand	180.000 tons

3.2.7. France

Feldspar production in France is confined largely to the southern half of the country, and is dominated by "Societe du Feldspaths du Midi at Salvezines in Aude and Societe du Feldspaths du Morvan at Etang sur Arroux", owned by "Groupe Mineral Harwanne", their combined capacity is 375.000 tons/year, mainly for ceramics(60%) and glass(40%).Production is about 130.000tons/year.Feldspaths produces about 140.000 tons/year of soda and mixed feldspars at Camp Cartier and Radh, St. Arnac, and at Lansac Castillet. (Pascal,1979)

The 200.000 tpa produced by Feldspaths du Midi includes the output from the former ceratera operations at Claudies. The predominantly sodium feldspar is supplied to the ceramics industry. (Bolger,1995)

3.2.8.Greece

In 1994, the country's major quartz and feldspar producer, state-owned Mevior SA, was purchased by Dr Eng. G. Georgiades for £1.07m. The Privately-owned company, which also exploits quartzite at its mines 25-30 km north of Thessaloniki , produced 36.000 tons of 0-6 mm sodium feldspar. Of this total, 200.000 tons were for export to Italian tile manufactures, with the remaining 16.000 tons being consumed by the domestic market.(Bolger,1995)

3.2.9 Italy

The main area of feldsphatic mineralization in Italy is the northern Alpine arc in the provinces of Vercelli, Novara, Brescia, Como, and in particular Trento. Italy has traditionally been the largest feldspar producer in Europe and from 1994 USBM statistics is easily the largest in the world. (Robbins,1986)

Today Italy consume around 1.5 m. tpa of feldspathic minerals of which about 50 % is used in the production of sanitaryware., glass and glazes. Currently about 75 % of ceramic production is exported, where 4-5 years ago this figure was 45-50 %. Although the Italian ceramic industry is currently doing well and showing significant growth, there has been a dramatic increase in the amount of feldspar imported from Turkey. The Italian feldspar producers are feeling the squeeze, since ceramic manufacturers can import material from Turkey at a more competitive price than domestically produced material. In 1994, Turkey exported around 350.000 tons of feldspar to Italy.(Bolger,1995)

3.2.10 Norway

Norway is traditionally associated with the production and export of nepeline syenite, although feldspar is also produced. The companies 1994 nepeline syenite production figures were in the region of 330.000 tons, althogh the processing plants' total capacity was 370.000 tpa. The company supplies around 70% of its output to the glass manufacturing industry, approximately 28% to manufacturers of ceramic bodies and 2 % for use in fillers. (Bolger,1995)

The Lillesand operation on the southern coast of Norway produced in the 24.500 tons potash feldspar and 43.000 tons ceramic industries with approximately 901% of the potassium feldspar being consumed by the glass industry and the remaining 10% supplied to the ceramics industry. (Bolger,1995)

3.2.11 Portugal

Portugal's feldspar production is principally located in the north of the country, in the region around Braga, where granitic pegmatite occur. Commercial feldspathic deposits are predominantly of potassium feldspar and are generally small scale operations, although the total national output in 1991 was almost 98.500 tons. In recent years, the country has been suffering from a shortage of new high quality deposits, as older small deposits become worked out. Affords are currently underway to explore for, and evaluate new deposits, especially in the area west of Guard where applet-bearing pegmatite occur. (Bolger,1995)

Portugal's main producer, Unimil-Minerals Ltd., has several feldspar concessions in the Porto and Braga are as, with its main quarry and processing plant located at Arreigada. (Nunes de Almeide, Thöbe, Cordez,1983).

3.2.12 Spain

The main consumer of feldspar in Spain are manufacturers of floor and wall tiles, the market for which is currently expanding, although sales to table ware and glass produces have declined sharply over the last decade.

Annual production is approximately 85.000 tons of potassium feldspar, 60.000 tons of feldspatic sands, and 220.000 tons of quarts in eastern Spain, around the town of Llança in the province of Girono and just 17 km from the border with France, Llansa SA produce 20.00 tons/year of sodium feldspar (6.8% Na_2O, 2% K_2A) and 50.000 tons/year of mixed sodium-potassium feldspar (4.3% K_2O, 4.8% Na_2O). (Bolger,1995)

3.2.13 India

Feldspar is known to occur through India in all but three states. The most important feldspar producing regions are Andhra, Pradesh and Tamil Nadu. Feldspar for export genet-rally comes from Tamil Nadu and Andhra, Pradesh as these areas are closest to port loading facilities.

Gimpex Pvt. Ltd. and its partner Shri Vijya yalakshmi Minerals Trading Co. have a feldspar deposit at Gudur in the Nellore district of Andhra, Pradesh, which covers and area of over 170 acres. The semi-mechanized operation has a capacity of 100.000 tpa. For 1995, the company expects to increase production from the mines to 112.000 tpa, with 100.000 tpa being processed. (Bolger,1995) three potash feldspar mines at Pippingarra, Mukinbudin, and Londonderry in Western Australia, and a sodium feldspar mine at Broken Hile in new South Wales. The company's processing plants are situated at Welshpool, Allendale in Victoria; Granvile, near Sydney and Pasir Gudang in Malaysia. Products include a full range of potas, soda and blended feldspars which come in a range of particle sizes for use in ceramic bodies, and in glass manufacture. CML and its Malaysian subsidiary supply glass and ceramic industries ,both within Australia and New Zealand as well as Japan, Korea, Malaysia, Philippines, Singapore, Thailand, Taiwan and Indonesia.(Bolger 1995). Major producers are given in table 3.2.

Table 3.2 Main Feldspar Producers of Australia. .(Bolger 1995).

Company	Region	Products	Capacity (tons)
Commercial Minerals Ltd.	Western Australia New South Wales	Na/Kfeldspar Feldspar	80.000
Minerals Corporation Ltd.	Brocken Hill New South Wales	Na/K-Feldspar and Aplite	220.000 45.000

3.2.15 South Africa

National feldspar output in 1993 was 56.800 tons, up 15% on the previous year. Almost all of the country' s production was a sodium/potassium mix, most of which was for domestic consumption. South Africa also has some low quality nepheline, syenite deposits, although the heavily Fe_2O_3 contaminated material is currently only used as roadstone. The majority of production is consumed by the domestic industries, but some material is exported to Spain, Portugal and Germany. CIM is currently looking further deposits close to the coast but is not willing to compromise the quality of the material produces for the sake of expansion. (Bolger,1995)

Almost all of the company's production was sodium/potassium mix, most of which was for domestic consumption. South Africa's s major feldspar producers are given in table 3.3.

Almost all of the company's production was sodium/potassium mix, most of which was for domestic consumption. South Africa's s major feldspar producers are given in table 3.3.

Table 3.3 The Major Feldspar Producer of S.A. (Bolger,1995)

Company	Region	Products	Capacity
Permian Ltd.	Northeastern Transversal	Quartz Feldspar and Mica	65.000 tons
Ceramic&Industrial Min.	North Cape and Transversal	K-Feldspar	45.000 tons

3.3 Developments in Titanium Industry

Titanium dioxide pigment manufacturing companies have been through a bad patch. Profitability dropped as companies witnessed the average world price of their products fall by some14% during 1996,at a time when raw material prices were increasing. In 1997, a slow crawl to recovery, began marked by several price increases. However, these increases failed to bring 1997's yearly average to the some level as that seen during 1996.(Catherine,1998)

The first, and largest, of the consolidations was announced in the second half of 1997. E.I. Du Pont et Nemours & Co Inc. concluded a deal to buy the majority of ICI's trioxide group, its closest rival. When the deal is finalized, it will leave Du Pont with an estimated 40% of the world pigment market- by far the world leader. (Catherine,1998)

The second structural change to the industry came when Millennium Inorganic Chemicals made a move on Rhone-Poulenc's subsidiary, Rhone- Poulenc Thann et Mulhouse, bringing Millenium's installed capacity to 611.000 tons, or 14 % of the world total.

But while those two noves so close together would seem to have been ample restructuring, for the time being at least, they appear only to have been the start.

Consolidation and acquisition has continued into 1998 with the announcement that Kerr-McGee has reached an agreement with Bayer to acquire 80% of Bayer's European TiO_2 activities, increasing its capacity to 303.000 tpa. Bayer's joint venture in Brazil, Tibras, is also for sale, although no firm offer has yet been received.

And there is still some tidying up to do. Once the ICI/ Du Pont deal has been finalized, ICI will then look to sell its North American TiO_2 operations which include a 50% interest in the 100.000 tpa Lake Charles plant, and a pigment finishing plant in Tracy, Quebec.(C.SİMS). (Catherine,1998). Changing shape of the global TiO_2 industry are given in figure 3.6. and 3.7.

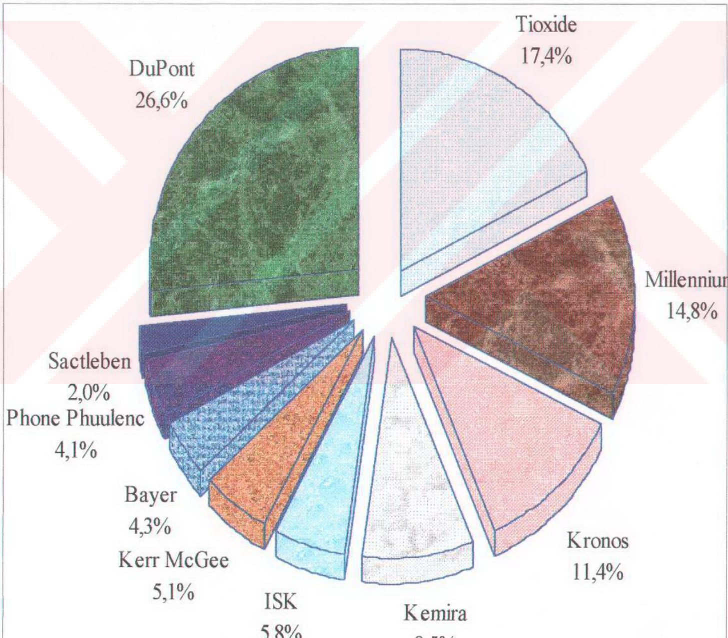

Figure 3.6 World capacity share of top ten producers 1996. (Sims, 1998).

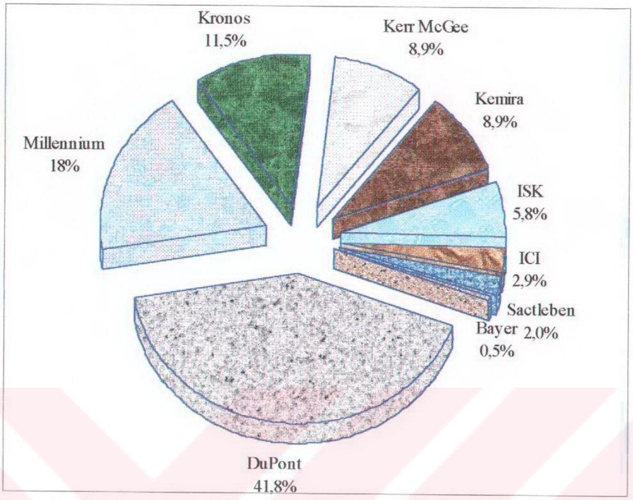

Figure 3. 7 World capacity share of ownership of the same operations (1998). (Sims,1998).

3.4 Turkey's Titanium, Reserves Production and Consumption

The increasing demand for titanium minerals, especially rutile, has sparked interest in the abundant domestic titanium resources of the Turkey. Turkey has not got high grade of titanium resources, which has economic importance. On the other hand some ferric deposits contain titanium minerals. Turkey' titanium reserves are given in table 3.4.

Titanium is used to manufacture titanium pigment, an ingredient in surface coatings in Turkey. Because of its high refractive index, rutile imparts white useful for paper coatings. Another main use of titanium are in the manufacture of titanium sponge, welding-rod coatings, ceramic and glass formulations, carbides and special alloys. Somewhat apart, in aerospace applications, titanium metal is useful because of its high strength to weight ratio.(Llewellyn,, Sullivan,,1990) Contemporary paint industry, where titanium was used majority, consumption amount is given in Table 3.5.

Table 3.4 Turkey's Titanium Reserves

Region	Reserves(,000 tons)	(TiO_2/Fe_2O_3 %)
Niğde-Ulukışla	100	0.06/ unk.
Kütahya-Simav	250	0.50/ unk.
Bingöl-Avnik	4.570	2.00-0.50/ unk.
İstanbul-Sile	0.500	14.70/ unk.
Gaziantep-Islahiye	120.000	2.00-8.00/25.00
Hatay-Payas	80.000	4.50/21.00-35.00
Konya-Isparta-Akşehir	76.000	4.7/26.00
Malatye-Hekimhan-Hasan	1.160.000	0.77/17.00
Adana-Osmaniye-Çotlu	48.000	8.70/25.00-67.00
Çarşamba-Perşembe-Ünye	80.000	6.9/58.00
İzmir-Ödemiş*	11.000	1.10-1.80/unk
Manisa-Gördes*	9.200	0.50-1.11/unk
Uşak-Eşme*	12.000	1.00-2.00/unk
Köseler-Benlieli*	45.000	0.5/unk

Source: DPT 7th. Five Years Developing Plan; Ankara,1997 (* Proved Reserve).

Table 3.5 Manufacture of paints.

Years	1990	1991	1992	1993	1994
Cellulose based paints	6.95	11.02	9.61	12.24	9.29
Natural oil synthetic	44.90	53.13	60.82	43.77	44.80
Plastic emulsion paints	50.77	62.72	60.84	69.71	57.90

Source: DIE. Annual Statistic (1988).

3.5 Feldspar Reserves In Turkey

The largest feldspar producing region in the west of the Turkey, with the main mining operations being in the Aydın, Çine and Muğla- Milas regions, located around the port Güllük. Raw materials, which is used as an feldspar source in Turkey, are pegmatite, aplite and feldspar felon and granites. The important feldspar sources are mined in the southern region of the country. Turkey feldspar. Albite sodium feldspar is produced mostly. Most of the Turkish feldspar produced is sodium feldspar, the bulk of which is consumed by the ceramics industry. Reserves of potassium feldspar are fewer in Turkey. The feldspar reserves in Turkey are estimated to be at least 410 million tons. (Toye,1997) Domestic feldspar reserves are shown in table 3.6.

The Mineral exporter's Association (MEA) expects that the total production and consumption are given in figure 3.8. In addition, some companies and their feldspar reserves are listed in table 3.7. On the other hand, The principal types of feldspar mined in Turkey are shown in table 3.8.

Table 3.6 Feldspar Potential of Turkey

Region	Reserves (Tons)
Ankara-Beypazarı Oymaağaç	315.748.000*
Aydım- Çine- Sarıkısık	75.000*
Bilecik- Küreköy	500.000*
Bilecik- Söğüt- İnhisar	10.000**
Kütahya- Simav- Söğüt—Kalkanköy	2.240.000***
Manisa- Gördes- Çanaklı- Kurtalan	100.000***
Bilecik-Söğüt-Hamitabad	275.000**
Kırklareli-Üsküp-Yurdalan-Sezerköy	10.800***
Manisa- Demirci- Virancık	1.525.000***
Manisa- Demirci-Söğütçük	2.500.000*
Eskişehir-Bozüyük	167.000**
Balıkesir- Bandırma- Alacık	20.557

Source: MTA Magazine,1994 & 6th Five years Developing Plan; Ankara,1996

*** Proven Reserve , ** Proven + Possible Reserve,*** Possible Reserve**

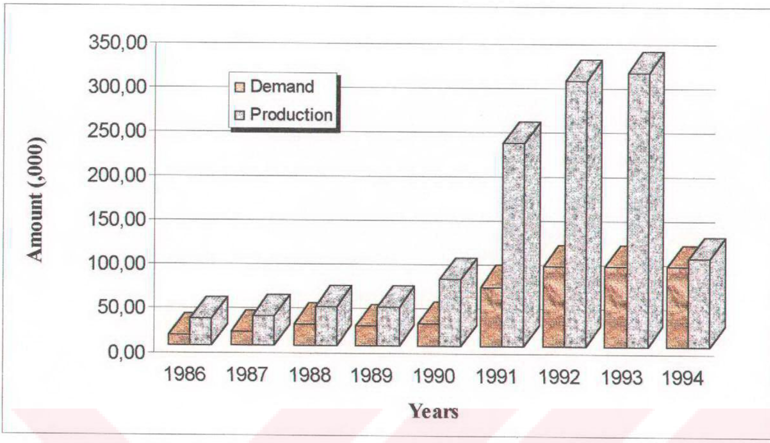

Figure 3.8 Demand and Production of Turkish Feldspar

Source: DPT. The Sixth Five- Year Development Plant
DPT. 1991 Annual Program
DIE. Annual Statistics (1985-1994)

Table 3.7 Turkish Feldspar producer and their reserves. (MTA ,1985-1990)

Company	**Reserves(Tons)**	
	Orthoclase	Albite
Toprak Mining Co.	150.000	400.000
Kaltun Madencilik	120.000	5.000.000
Komet Mining Co.	20.000.000	
Emmom Mining Co.	170.000	
Akmaden Mining Co.		5.000.000
Çanakkale Seramik Min. Co.	5.000.000(Granite,Nepheline,Syenite)	
Giydiren Mining Co.		250.000
Esan Mining Co.	200.000	500.000
Ahmat Karanfil	2-3 (Mio. tons)	
T. Şişe Cam Fabrikaları		1.000.000
Metal Hammadde Sanayi	200.000	

Table 3.8 Types of feldspar minerals mined in Turkey (MTA, 1985-1990)

Producer	Types of feldspar minerals
Esan Mining Co.	Albite-Orthoclase
Çanakkale Seramik Mining Co.	Albite-Orthoclase-Pegmatite-Alteregranite
Toprak Mining Co.	Albite-Orthoclase
Maten Mining Co.	Albite-Orthoclase
Söğüt Seramik Mining Co.	Albite-Orthoclase
Akmaden Mining Co.	Albite
Kaltun Mining Co.	Albite-Orthoclase
Necip Giydiren	Albite
Mehmet Tuncel	Albite
Feldsa	Orthoclase
Akmadencilik	Orthoclase
Hüseyin Akkoyun	Orthoclase
Varol Kürkçü	Orthoclase
Varol Mining Co.	Orthoclase
Servet Kapankaya	Orthoclase
Osman Aydın	Orthoclase

3.5.1 Domestic Feldspar Production and Companies in Turkey

The balance of power amongst the European feldspar producers, traditionally dominated by the Italians, is shifting and Turkey is emerging as a formidable new force in the world market, particularly within Europe. It seems that can stop the rise of the Turkish feldspar producers who are blessed with abundant reserves, and low labour costs.

Turkish Feldspar Production is dominated by private companies. In the last ten years there have been significant increases in feldspar production and exports, the most dramatic of which have occurred over the last few years. Between 1986 and 1992 domestic production rose from 100.000 to 400.000 tpa. This rapid expansion of the industry has led to fierce competition and aggressive pricing policies. The latter has allowed several companies to develop considerable export trade with Italy, Spain, and Germany. According to Mineral Exporter's Association (MEA),Turkey exported over 250.000 tons of feldspar in 1992, and this was described as adissapointing year by some of the producers. As with beige clay and kaolin, the main feldspar producers are those with a connection to ceramics manufacturers. As yet, little glass grade feldspar is produced but several companies are beginning to investigate this area. (Bolger,1995)

Esan Eczacıbaşı Industrial Minerals Co. produces sodium and potassium feldspar from its mines. In the Milas and Çine regions. After axtraction the material is transported to the processing plants at Güllük and Milas. The company has the capacity to produce 200.000, tpa of crushed and blended feldspar from its Güllük plant and a total of 55.000 tpa from the Milas dry grinding and flotation plant. Although the Milas facility was running at full capacity in 1994.the Güllük plant was only operating. At around 75 % capacity. A production increase of around 5000 tpa is expected at the Güllük plant during 1995 and an almost 50 % increase in output is anticipated at the Milas flotation plant, is capacity being expanded from 40.000to 70.000 tpa. The crushed sodium feldspar from Güllük is produced in two grades , which have different amounts of the coloring impurities TiO_2 and Fe_2O_3. (Bolger,1995)

Sodium feldspar from the Milas flotation plant comes in two grades depending on particle size (-500+80 μm) , and (-150 μm). The grinding plant and Milas also produces a very (fine grade of sodium feldspar, which is ground to -63μm. The remainder of the material from the grinding plant at Milas is a potassium feldspar of

–63 µm size. The company's products are mainly exported to Italy and Spain, although it also exports flotation feldspar to South East Asia.(Seyrankaya,1995)

Metal raw metarial SvT AS operates a number of open cast sodium feldspar mines, exploiting augen-gneiss and magmatic genisses , within the Menderes massive in the south –west of Turkey. Metal belongs to the Elginkan Holding group of companies , which has interests in the ceramics, construction and medical and pharmaceutical industries, although some is exported for the production of floor tiles. The 1994 output is just over 100.000 tpa was 60% higher than the previous year. The company aims to produce 130.000 tons sodium feldspar in 1995. The company's launching a new product for 1995, a super white feldspar with maximum Fe_2O_3 and TiO_2contents of 0.10% and 0.08% respectively. Metal also has two small potassium feldspar quarries in West Anatolia, which produced around 2.500 tpa in 1994 production levels area expected to remain the same during 1995, with all of the crushed and ground material produced being marketed domestically.

Kale Mining Co. is part of the Kale Group of companies, which is one of the larger mining companies in Turkey. Kale Mining Co. processes albite ores in the Çine area and exports through the port of Güllük. The company has also established a quartz/feldspar micronising plant that can custom grind minerals 0.0 to 150 m.

Ranar Mineral Industries Inc. is different in that the company has no associates involved in ceramics production. Ranar also prefers to subcontract mines to local concerns, purchase the crude ore, process it and then sell it on. The company has contracts for the processing of feldspar and sells to both local and overseas consumers.(Bolger,1995)

Toprak Mining Co.mines Na-Feldspar around Milas for the group's ceramic production and also exports more than 50.000 tpa to Europe, mainly Italy. The company operates one grinding plant and is planning to install a second near the mines in 1994. Toprak Mining Co.is working on developing a mixed 50/50 Na-Feldspar/ K-Feldspar product and may begin production next year. The producers is include Çine Akmaden Mining Co. and Söğüt Mining Co. are also believed to be mining feldspar deposits in Turkey. Figure 3.9. shows domestic feldspar production between 1982-1994.

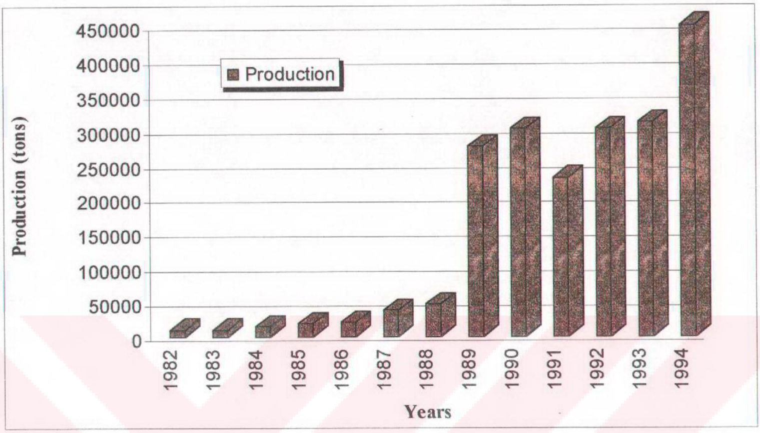

Figure 3.9 Domestic feldspar production.

Source:6th Five years Developing Plan; Ankara,1996.

CHAPTER FOUR
MARKETİNG

4.1 Uses of Titanium

Titanium is an abundant element that has become significantly useful industrially to man only within the past 100 years. Its principal uses are related to requirements and wants of modern industrial technology and affluent societies. The future titanium mineral supply will certainly involve an increase in the supply of beneficiated products, namely, titanium slag and synthetic rutile. Titanium dioxide or titan, is the most widely used white pigment. Most of the titanium minerals produced today are used to make TiO_2, white pigments. A small portion go to produce titanium metal or for use as a welding rod flux.(Brobst, Pratt,1990)

Table 4.1 Analyses of Commercial Titanium

Element %	Rutile(%)	Ilmenite(%)
$TİO_2$	95	50-65
Total Fe	2-3	20-35
AI_2O_3	0.40-0.90	0.60-2.20
SiO_2	0.50-1.00	0.60-2.30
Other	2.1-0.6	28.8-10.5
Total	100.00	100.00

Source: Industrial Minerals and Rocks,1988

4.1.1 Sulfate Pigment Manufacturing

In the sulfate process finely ground ilmenite or high TiO_2 slag is digested with strong sulfuric acid, forming a solid, porous cake which is dissolved in dilute acid and water to yield solution of titanium sulfate ($TiOSO_4$) and iron sulfate.(Langtry,Stanley,1988). For many years TiO_2 pigments were manufacture by reacting ilmenite with H_2SO_4.Leucoxene and rutile can't be used in this process, because they're either insoluble or partially soluble in H_2SO_4. In this exothermic process, ilmenite and H_2SO_4 are reacted to form titanium sulfate and iron sulfate. The titanium sulfate is chemically clarified and then calcimined to form TiO_2 (anatase), ground and then further treated by precipitating coatings of various compounds on the particle surfaces to improve the product. The finished pigments are then used in paints, plastic, paper, synthetic fibers, etc. Lynd and Lefond (1983) state that the sulfate process produces large quantities of spend acid and iron sulfate (copperas)-up to two kg. Waste per 0.5 kg. of TiO_2 pigment. Spend acid and copperas are very noxious materials which make their disposal difficult in these environmentally regulated times.(Garnar,1994) The solution is then concentrated, and the titanium is precipitated by hydrolysis, filtered, calcined at 900° to 1000 °C to the oxide, and further treated prior to the finished pigment stage. The estimated tons of raw material required to produce one ton of TiO_2 are as follows:

Iron scrap	0.1-0.2
Ilmenite or titanium slag	1.5-2.8
Sulfuric acid	3.0-4.0

Ilmenite or titanium slag are dissolved in sulfuric acid, iron and insoluble residues are removed. A hydrous titanium dioxide is precipitated, and calcined afterwards. .(Langtry,Stanley,1988).

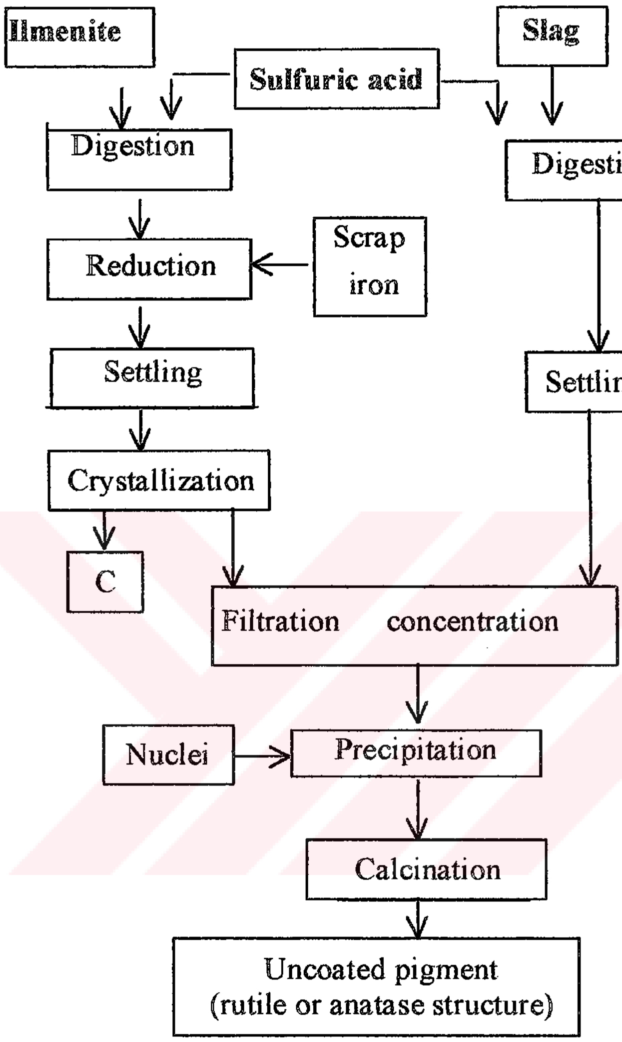

Figure 4.1 Pigment production by the sulfate process. (C: Copperas "iron sulfate") (Dormann,1994)

Specifications: Specifications for titanium minerals wary with the buyer and the application. Sulfate pigment producers look for ilmenite product that are high in ferrous iron with 2 % insoluble titanium minerals. Ores with low chromium are also required in order to eliminate yellowing caused by this element. Titanium slugs in Canada and unacceptable to chloride pigments producers.

4.1.2 Chloride Pigment Manufacturing

In the chloride process, titanium tetrachloride ($TiCL_4$) is produced by chlorinating titaniferous, higher-grade materials at about 850° to 900°C in the presence of petroleum coke. (,Dormann, Lefond,1994).Pigment is manufactured by reacting TiO_2 raw materials with hot chlorine gas producing $TiCL_4$ and. The $TiCL_4$ is oxidized forming TiO_2 (rutile). The chlorine from this step is recycled back to reactor and it is used over and over again. (Garnar, 1994). The estimated tons of raw materials required to produce one ton of TiO_2 are as follows:

Rutile	1.1-1.2
Chlorine	0.1-0.2
Petroleum coke	0.1-0.2
Oxygen	0.4-0.5
Aluminum chloride	0.03

Titanium tetrachloride $TiCL_4$ ("tickle") is separated from other metal chlorides, then the pure $TiCL_4$ is oxidized to TiO_2. Figure 4.2.

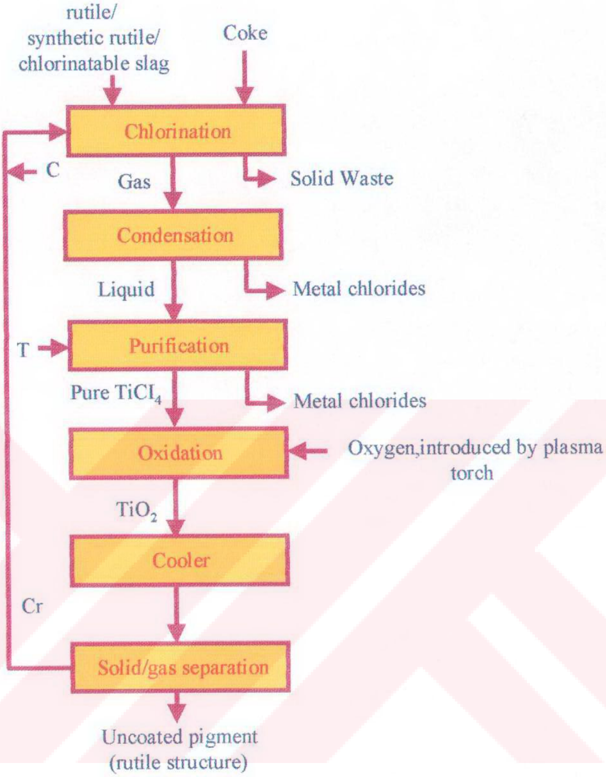

Figure 4.2 Pigment production by the chloride process (C: Chlorine ; Cr: Chlorine recycle T: Treating agent). (Dormann,1994).

Stringed environmental regulations are making high TiO_2 feedstock necessary for complains, thus most producers are using slug, synthetic and natural rutile instead of ilmenite feedstocks.

Certain elements (e.g., Mn,Mg,Ca,P,etc.) form chlorides that have boiling points higher than the temperature in the titanium mineral/chlorine reactor. These cause " the bed two stick" and eventually the reactor has to be shut down in order to remove them. The more of these impurities present in chloride feedstock, the more the shutdowns are. The presence of radioactive elements (U and Th) are also unacceptable in titanium ores. Finessed pigments are available in both the rutile and anatase forms. TiO_2 pigment's most important properties are : High degree of reflectivity giving them brightness; chemical inertness to solvents except HF and hot H_2SO_4; thermal stability; and non- toxicity. The rutile form tends to be more abrasive and is used in the paints, plastic, printing inks, and cosmetic industries. The anatase form is better suited for uses in the manufacture of paper, textiles, latex, (Garnar,1980)

4.1.3 Ilmenite Beneficiation:

There are large tonnage of ilmenite throughout the world that cannot be used directly in pigment manufacture because TiO_2 is too low or the impurity levels are too high.

The titanium slag is cooled, crushed and screened prior to shipment. Because the Sorel slag contains impurities that are detrimental to the chloride process, only. Sulfate process pigments producers can use it.

Federal and state regulation of toxic chemical waste has made it almost mandatory that chloride pigments. Producers use high TiO_2 feedstock in order to minimize the amount of waste material to be disposed. Several process, using oxidation, reduction, leaching, and / or chlorinetion to remove the iron, have been developed to produce high TiO_2 materials from low grade ilmenite. at present, all of the producers use beach sand ilmenite as starting material. (Garnar 1994).

4.1.4 Titanium Metal Manufacture

The future for titanium mineral feedstock supply will certainly involve an incre ase in the supply of beneficiated products, namely, titanium slag and synthetic rutile. In fact, with the exception of one or two possible mineral production projects for the supply of sulphate grade ilmenite, every new major supply project will be linked to one or other of the two forms of beneficiation.(Richard, Taylor,1995)

Only 5 to 6 % of world titanium mineral production is used to make titanium metal sponge. This is produced using the Kroll process in which titanium minerals are reacted with elemental chlorine. The resulting titanium tetrachloride is then reduced using molten magnesium forming a sponge. One kilogram of metal is produced from 4.37 kg of tetrachloride by reducing with 1.41 kg of magnesium. Finished products are made from the sponge.(Garnar,1994)

Titanium has many good properties including exceptional strength to weight ratio, corrosion resistance, high melting point, high electrical resistively, low thermal conductivity, low coefficient of expansion. These properties of titanium make it valuable in casting jet engines, aerospace applications, aircraft structure, marine hardware chemical equipment, etc. Current about 6 % of the aircraft's empty weight. (Garnar,1994)

4.1.5 Miscellaneous Uses

Titanium, formerly used mainly as a deoxidize, has assumed considerable importance in the manufacture of stainless steels as a carbon and nitrogen-stabilizing element to inhibit intergranular corrosion. Small amounts of titanium minerals go into other uses. Ilmenite has been used in filter beds, sand blast abrasives, foundry sands, and as high density fillers. (Langtry,Stanley,1988)Small amounts of are used as a welding rod coating where it aids stabilization of the arc and frees the metal of slag. It is also used as an opacifier in ceramic glazes and to produce tan-colored glass.

Table 4.2 Typical slag Analyses

Content	Soreslag	RB Slag	Tinfos Slag
TiO_2	77.50	85.80	75.00
Cr_2O_3	0.17	0.17	0.09
FeO	10.90	10.80	7.60
SiO_2	3.00	2.10	5.30
MgO	5.30	1.10	7.90
Al_2O_3	3.50	1.30	1.20
U+H	1.90 ppm	15.0-30.0 ppm	na

Source: Indusrial Minerals; April, 1995

4.1.6 The Other Uses of Titanium

Titanium has a high refractive index and good brilliance, absorbs ultraviolet light, yet reflects all Wave lengths of visible lights.TiO_2 is very resistant to chemical attack, being inert the most acids and alkalis. Further advantages of TiO_2 are its high tinting strength and its non-toxicity.

Titanium is important constituent of white and colored paints and coatings. Plastics are the second largest end-use for titanium. Titanium dioxide colors plastics and protects them against ultraviolet light. TiO_2 improves opacity and print quality, and increase brightness of paper. The pigment is especially used in high quality printing and writing paper. Other pigment applications comprise rubber, inks, ceramics and glazes as well as synthetic textile fibers. Anatase is much more active photocatalyst than rutile: paints made with anatase pigment fail rapidly by "chalking" on exposure to ultraviolet light. The durability of paints, however, can be improved by coating anatase and rutile pigments. Electrodes and fluxes are used in electric are welding to stabilize the arc, to protect the weld pool, and the remove impurities from the latter. Other pigment applications comprise rubber, inks, ceramics and glazes as well as synthetic textile fibers.(Dormann,1994)

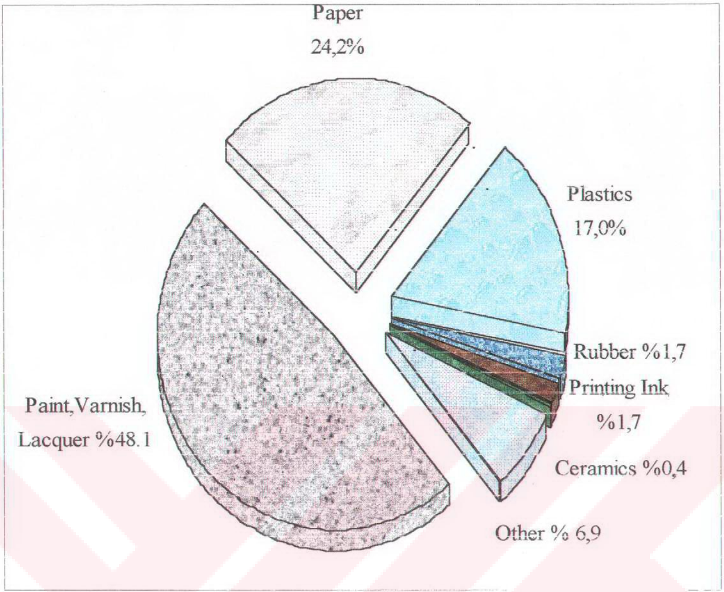

Figure 4.3 Titanium Pigment Consumption (USA)

Source: The Industrial Minerals Hand Book (1992)

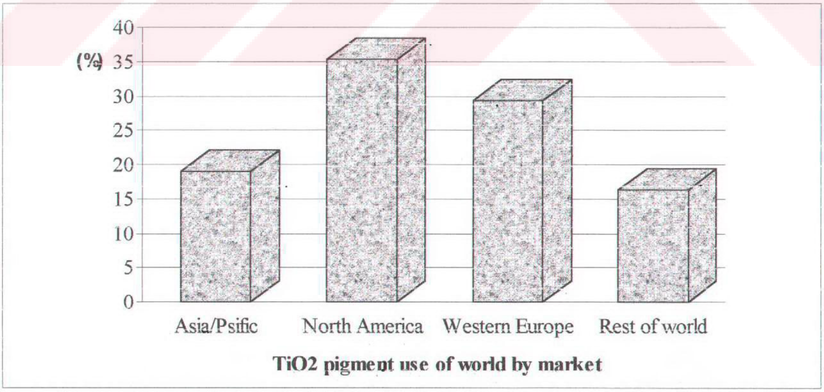

Figure 4.4 Titanium pigment use of world by market.

Source: Erzmetall (January,1994)

Titanium and titanium alloys find applications aerospace industry: in aircraft turbines, structural members in aircraft, and space vehicles. In chemical and general engineering, titanium is used for tubing handling aggressive solutions, for example in water desalting plants and oil, gas cooler.(Dormann,1994).

4.2 Uses of Feldspar

There is no significant consumption of feldspar in the raw ,unprocessed state in which it is taken from the mine and, although the degree of commination may vary according to the requirements of different end uses, the majority of users acquire their supplies already ground and sized, either by the primary producers or by merchant grinders.(Smith,1974;Potter,1980)

The two properties of feldspar that make it useful to industry are its alkali and alumna content. For world countries it is estimated that 85-90 percent of feldspar and nepheline syenite produced is consumed by the glass and ceramics industries.

The two properties of feldspar that make it useful to industry are its alkali and alumina content. The properties which make nepheline syenite valuable are essentially the same as those for feldspar and 6thus the two materials frequently compete for the same markets. For countries outside the former communist bloc, it is estimated by the glass and ceramics industries, although the proportions vary from country to country.(Bolger,1995).

4.2.1 Ceramics Industry

Feldspar is used in ceramic mixtures, such as those for the making of vitreous china and porcelain enamels, principally as a flux. In the manufacture of white ware ceramics, feldspar is the second important ingredient after clay. During ceramic manufacture, the alkalis act as flux. The feldspar melts before the quartz or clay components and wets the remaining solid particles, pulling them together through surface tension. The type and amount of flux present controls the degree of nitrification.(Toye,1997)

Table 4.3. Properties of Using Feldspar in Eczacıbaşı Ceramic Factory.

K_2O+ Na_2 O	min. 8.00%
Fe_2O	max. 0.25%
TiO_2+CaO+MgO	max.2.00%

Source: D.P.T. Fifth Five Years Developing Programs, Ankara, 1986

The choice between Na and K-feldspar is largely the result of a trade-off between the various properties and effects of the two minerals. Sodium feldspar is preferred by many ceramic body and glaze manufacturers as it acts as a stronger flux than potassium feldspar. An increase in amount of potassium feldspar in a ceramic body the effect of increasing the refractoriness of the produced material.

Ceramics produced using sodium feldspar are generally weaker in terms of modules of repute than those using potassium feldspar. In porcelain enemas, potassium feldspar is preferred as sodium feldspar tends to cause "fishscaling" on the tired surface. Potassium feldspar, which tends to be most costly, is often used in the manufacture of high voltage electrical porcelain, where the technical advantage that it affords over sodium feldspar justify the new extra raw material cost.(Ermiş,1995)

Table 4.4 Typical Feldspar Content in Common Pottery Bodies

Electrical Porcelain	30-50
Sanitary ware	25-35
Hotel chine	15-35
Chemical porcelain	15-30
White ware	15-30
Floor and wall tiles	10-55

Source: Industrial Minerals and Rocks, (Mudd,1992)

4.2.2 Glass Industry

Feldspar is added to glass making formulas to bring alumina ,together with the accompanying alkalis, into the melt. The added alumina enhances the workability of the molten glass and improves the finished product by giving it better chemical stability and inhibiting any tendency toward devitrification. The increased workability facilities the operation of automatic machines for shaping jars and bottles, materially reducing the spoilage ratio. Greater chemical stability broadens the usefulness of the containers.(Bolger,1995)

The container and sheet glass industries also make use of the high alumina content presence of alkalis in both feldspar and nepheline syenite. The alkali content again acts as a flux, lowering the batch melting temperature and therefore reducing the amount of relatively expense soda ash required. Alumina acts as a matrix former reducing the tendency for glass to denitrify. The alumina content also acts as a stabilizer, which improves the chemical durability of glass as well as its physical resistance to starching, bending, breaking and thermal shock.

Table 4.5 Properties of Feldspar Used in Glass Industry

Na_2O (%)	10.00
Al_2O (%)	18.50-22.50
SiO_2 (%)	66.00-68.00
Fe_2O_3 (%)	0.08

Source: The Industrial Minerals HandyBook. (Harben,1992)

Feldspathic Al_2O_3 content can be 1.5-2 percent for container and flat glass, and up to 15 percent for certain glass fibre. Sodium feldspar tends to be more popular in glass manufacture than potassium feldspar although the latter commonly used in glass for television screen.Fe_2O_3 content of feldspatic material used in glass manufacture is especially important, since its presence can discolor the final product.

4.2.3 Fillers and Extends

The market for value-added feldspathic minerals in paints plastic sand rubber remaining relatively small in terms of volume although it is still a significant amount. The physical characteristics of feldspar lend its to use as filler as extenders in plastics, paint and rubber, when finally ground to around 2 micron.

Paint: Feldspar fillers are used in both interior and exterior paints, which can be solvent of waste based. Such fillers are suitable , not only for highly pigment coating, but also in translucent stains an clear films.(Bolger,1995)

Beneficial properties of feldspar in paint and coating include;

- Good dispensability,
- Chemical inertness,
- Stable pH,
- Low viscosity at high pigment loading,
- Provides good film integrity, resistance abrasion, chemical attack and chalking,
- Excellent tint retention,
- Exceptional resistance to frosting,
- High dry brightness and low tint strength.

Plastics: Many of the physical properties of feldspar make it suitable for use in plastics.

Beneficial properties of feldspar in plastics include;

- Good dispensability
- Chemical inertness,
- Stable pH,
- Low viscosity at high pigment loading,
- Resistance to stains, abrasion, chemical attack,
- High dry brightness and low tint strength,
- Index of refraction is very close to most commonly used resins .

The largest application for feldspar is as a filler in plastics, PVC, epoxies, and polyesters.(Bolger,1995)

Rubber, Sealant and Adhesive Industries: As a filler material in rubber, sealant and adhesives the useful physical properties of feldspar is again similar to those common both paint and plastics applications, including the refractive index. (Bolger,1995)

4.2.4 The Other Uses of Feldspar:

Low grade feldspathic sands can be used as a sand blast media which is a potentially expanding market due to health concerns over the use of slica. Feldspar serves advantageously in abrasives and scouring soaps because of its fracture and inter mediate hardness. Its characteristic two directional feldspar to form sharp-edged, gritty particles hard enough to abrade and loosen many objectionable surface accumulations yet soft enough to avoid injury to the article being cleaned.

The increase in recycling, particularly aluminum cans could lead to slight increase in demand for feldspar. Because the mineral can be used to enhance combustion of flue gases, which are derived from the delacquering of aluminum drink cans, prior to recycling. Both feldspar and nepheline syenite are used in very small amounts as welding fluxes in welding electrodes, and also in the extrusion and binding of coating fluxes. However, to be commercially viable, feldspathic minerals have to be cost competitive with other more commonly used feedstock such as blast furnace slag. (Bolger,1995)

Feldspar is used in very small amounts as welding fluxes in welding electrodes, and also in the extrusion and binding of coating fluxes. A particle size around 70μm is the most commonly utilized.

About 65 % of all feldspatic material is used by the glass industry;30 % in ceramics; and 5 % in fillers and other applications. Aside from glass industry ,a very small tonnage of applite “fines’’ is used as a flux in brickmaking this is really a byproduct , high in iron, which has been removed prior to the magnetic separation step so as not to be detrimental to the process.(Potter,1980)

4.3 Prices

4.3.1 Price of Titanium

The driving force behind the success of the mineral sand industry is the demand for titanium minerals, and as over 90 % of these are destined for the pigment industry, it can be assumed that it is relative strength of this market that discates production levels and capacity utilization across the globe.(Skillen,1992)

The industry is now in a state of high stress. The demise of mineral price, reduced capacity and continued over supply is forecast to suppress the capacity and continued oversupply is forecast to surpress the industry for several years, having the most profound effect on those companies which have yet to develop downstream processing or failed to freeze the “crash” and are and thus committed to long term sales contracts. .(Skillen,1992)

Supply/demand balances combine the results of the previous two chapters, and show which raw material might be insufficient in supply. Supply/demand balances are derived for ilmenite and rutile. The demand for ilmenite and rutile is calculated by taking the demand of end-products, and adding factors as plant utilization, feedstock mix, and process efficiency. Supply minus demand gives the supply/demand balance; a positive figure describes an oversupply, a negative a shortage. As ilmenite presumably remains in oversupply, we can not except a price increase. Tight supply of rutile should result in a price rise. However, as synthetic rutile and chlorinatable slag are viable substitutes, and as production capacities for these materials are increasing, a higher price cannot be expected before the end of this decade. (Dormann 1994). Titanium prices are given in table 4.6. Ilmenite supply/demand balances are given in figure 4.5. Rutile supply/demand balances are given in figure 4.6.

Table 4.6 Rutile Prices

Australian concentrate,	**1994**	**1995**	**1996**	**1997**	**1998**
Bulk(large volume, for pigments)	\$370-400	\$480-520	\$575-675	\$ 490-540	\$ 500-550
Bagged(small parcels) for welding rods, etc)	\$420-440	\$570-620	\$800-1000	\$650-720	\$ 600-650

Source: Industrial Minerals, July 1994-1998

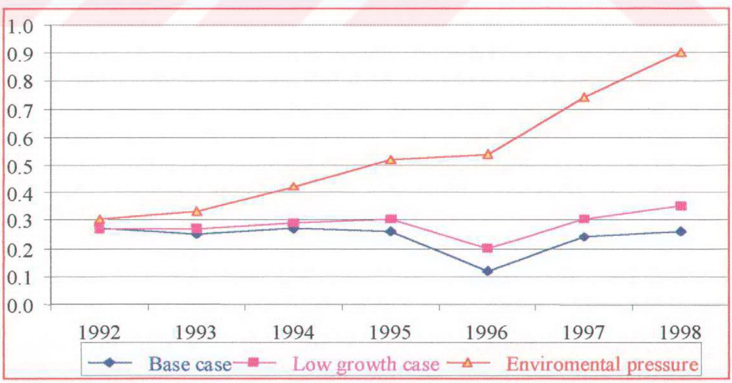

Figure 4.5 Ilmenite supply/demand balances(in mill. t. contained TiO_2). (Dormann 1994).

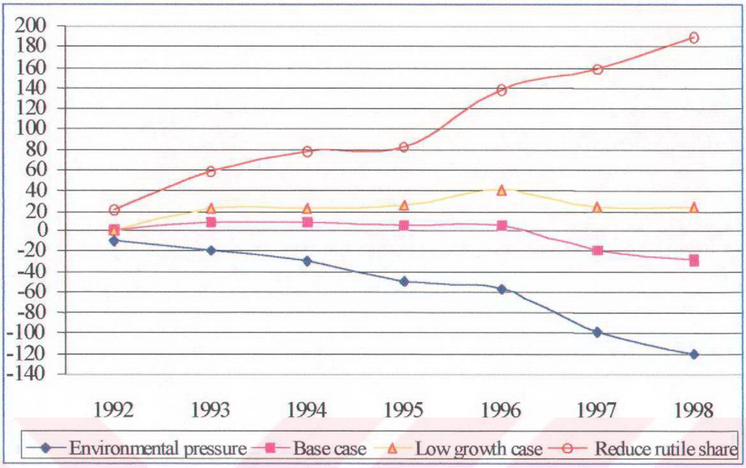

Figure 4.6 Rutile supply/demand balances (in 1000 t contained TiO_2). (Dormann 1994).

Between the peak and trough of the last global economic downturn in 1990- 1993 ,532.000 tons of new pigment capacity entered the market. In Europe, prices fell from 47.00 DM /tons in 1991 to 3.200 DM / tons in 1993, and in North America from 2.170 $ / tons to 19.00 $/tons over the same period. .(Fisher,1996).

In the TiO_2 pigments and minerals industries, There is a need for better forecasting techniques. It is estimated that 711.000 tons of new pigment production capacity will be built between 1996 and 2005.It will cost between 2.000 $/ tons and 3.750 $ / tons. The timing of this new capacity is the single largest factor influencing pigment prices.(Fisher,1996).

4.3.2 Price of feldspar

The last few years have not seen any significant emergence of new markets for feldspar, with the total of world production still being consumed by glass and ceramic industries. Process report many mining and processing operations working at full capacity and others planning increases in output for the coming year. Despite an increase in production volume, there has been little change in world prices over the last couple of years in what is still very competitive market. Prices of feldspar are given in table 4.7.

Table 4.7 Feldspar Prices

Years	1994	1995	1996	1997	1998
Ceramic grade, powder, 300 mesh, bagged, ex-store UK.	£160	£160	£160	£180-185	£180-185
Sand,28 mesh, glass grade, ex-store, UK.	£85	£85	£85	£99	£99
Ceramic grade, shortton FOB Spruce Pine, NC.					
170-250 mesh, bulk, (Na).	$59.80	$60-62	$60-70	$60-70	$60-70
200 mesh, (K)			$95	$95	$95
170-250 mesh, bagged (Na).	$76	$78-80			
325 mesh, bagged (Na).	$114.50	$114.50	$115-125	$115-125	$115-125
FOB Monticello,GA,200 mesh,(K).	$89	$95			$95
Glass grade, bulk, shortton FOB Spruce Pine,NC,30 mesh,(Na).	$38.50	$42			
FOB Monticello, GA, 30 mesh, (K)	$73.25	$80			
30 mesh, (Na)			$40-50	$40-50	$40-50
80 mesh, (K)			$80	$80	$80
S. African, FOB Durban, bagged Ceramic grade	$140	$140	$140	$140	$140
Micronised	$235	$235	$235	$235	$235

Source: Industrial Minerals. (July1994-1998).

The world container glass industry, although locally doing well, is generally under pressure from alternative lightweight packaging materials such as plastic coated paper cartons. The trend for recycling glass has still to make a significant impact on the container glass industry, although it remains to be seen to what extend this will remain true in the future, as environmental considerations gain a higher profile. (Garnar,1994).

Between 1988 and 1994, prices for Turkish feldspar generally fell, due to strong competition amongst suppliers. Turkey, as an major exporter, effected the market last a few years strongly. Significantly, not only has production increased domestically but amount of feldspar exported has risen sharply. The 1994 export figures show more than a four-fold increase on 1990.The trend looks set to continue with MEA (The Mineral Exporters' Association) predictions for 1995 exports at around 750.000

tons. Domestic consumption is not expected to increase significantly during the rest of this year.(Bolger,1995) Total Turkish feldspar exports are given in figure 4.7.

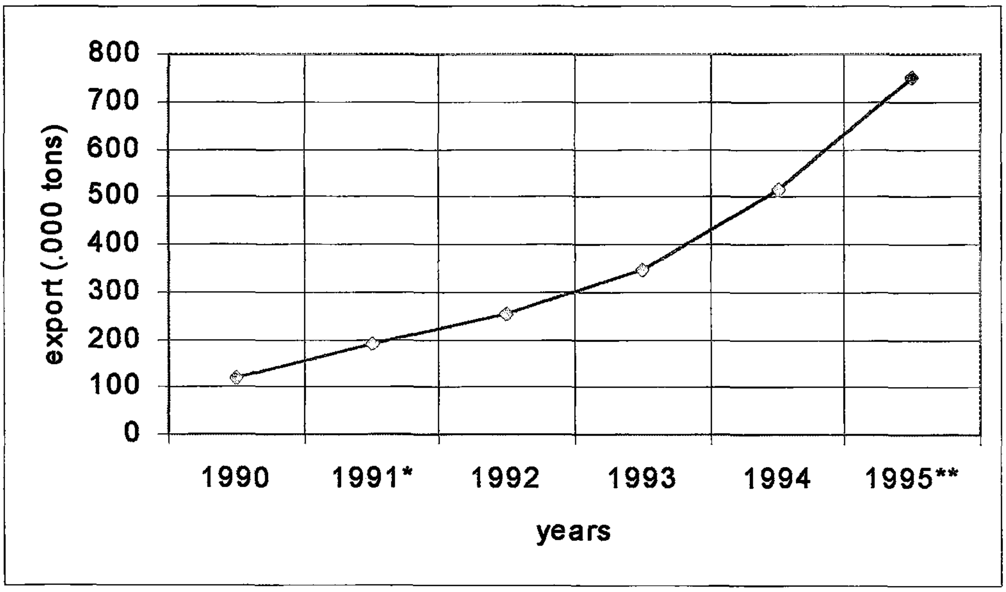

Figure 4.7 Total Turkish Feldspar Exports (* not available ,estimated). (Bolger,1995).**

CHAPTER FIVE
PLANT PRACTİCES OF TITANIUM AND FELDSPAR

5.1 Plant Practice of Titanium

Beneficiation of titanium depends on the nature of the deposit and on the nature of the deposit and on the demands of end application, as each application has its own specifications. For example, hardrock titanium are treated by gravity concentration and/or flotation. Here, the treatment for recovery of titanium ores are depicted a relatively recent development current flowsheets of mills operated NL Industries plant at Tahawus, Engebofjellet eclogite in Norway. Typically, the plant operations for separation of several titanium are given in these flowsheets.

The combination gravity concentration-magnetic flotation flowsheet of the NL Industries plant at Tahawus, N.Y., is given in simplified from in figure 5.1. Magnetite is removed from the ground ore by Low-intensity magnetic separation. Following this, relatively coarse ilmenite is removed by tabling, and this concentrate is cleaned by high-indensity magnetic separation. A locked magnetite–ilmenite fraction, removed magnetically, is returned to the grinding section. Nonmagnetic tailings are discarded. The-200 mesh fraction is deslimed at -10μm and +10μm fraction is concentrated by flotation. Flotation feed is conditioned at –70 % solids with tall oil, fuel oil, sulfuric acid, sodium fluoride, and frother and floated at 40% solids.(Aplan,1988)

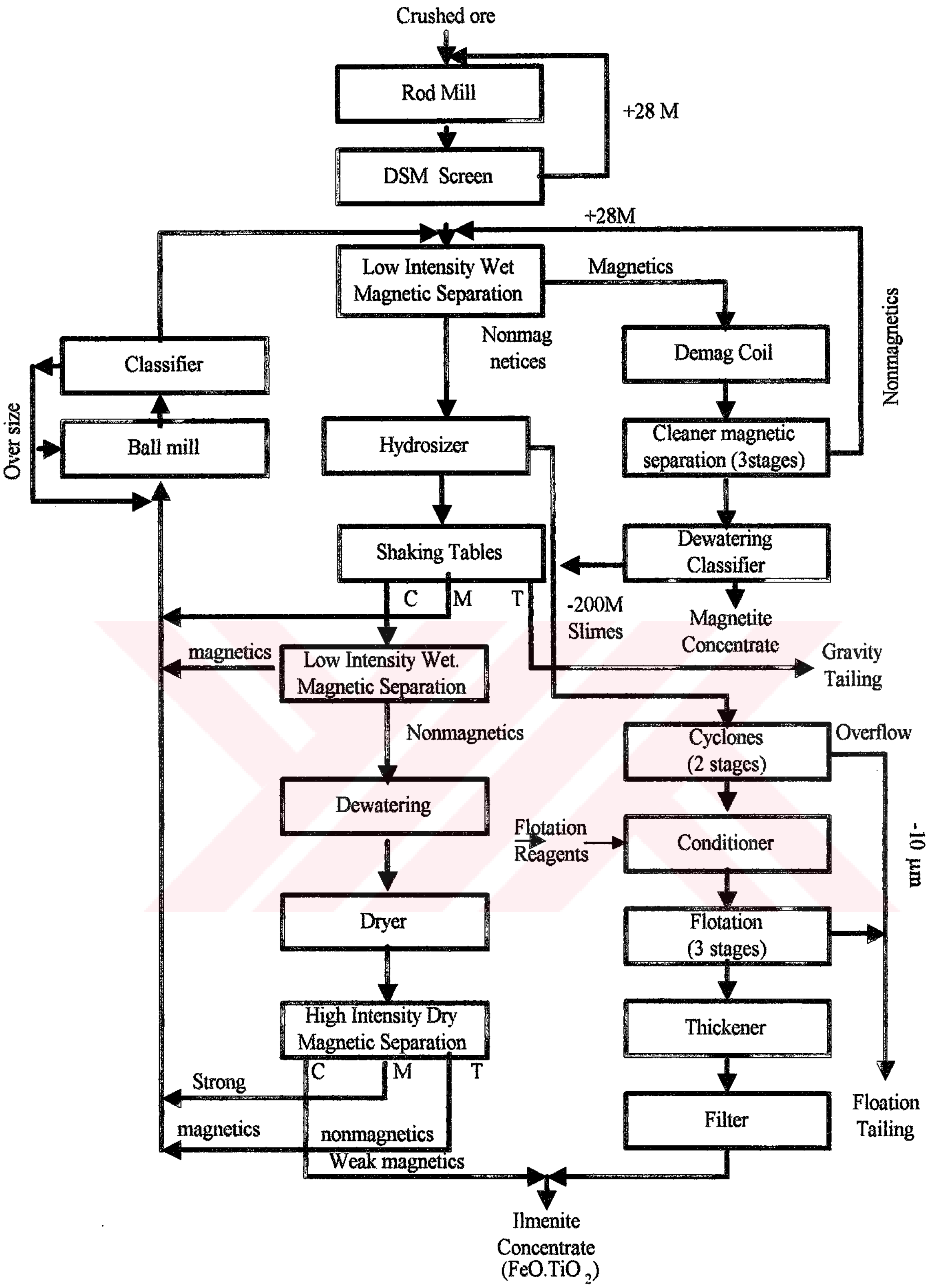

Figure 5.1. Simplified flowsheet of hardrock ilmenite concentrator, NL Industries, McIntyre concentrator, Tahawus, N.Y. (Aplan,1988)

Engebofjellet deposit in Norway: Engebofjellet' rutile deposit is the most favorable of the known deposits. It has a rutile content up to 3.5 to over 4 % in enriched zones; reserves might be over 400 mill.t of ore. Table 5.1 gives analyses of rutile concentrates from the Engebofjellet deposit. The concentrates have particle size between 75 and 200 µm, and were produced with laboraty equipment: Frantz magnetic separator and dense medium separator. Only unclean concentrate (Engebofjellet A) is too high in calcium oxide and alumina. An advantage of this hardrock rutile deposits is that their content of radioactive elements is practically equal zero.

Table 5.1 Analyses of rutile concentrates from the Engebofjellet Deposits.

Compound/ element	Engebofjellet*			Quality/ requirement.
	A	B	C	
Total TiO_2	92.88	95.38	96.35	min.85 (rutile<95)
Soluble TiO_2	3.98	2.67	1.62	
Rutile**	88.90	92.71	94.73	max.12 (rutile~0.6-0.9)
Fe_2O_3	4.66	2.25	1.67	

*** Engebofjellet, samples from rutile-rich part of deposit**

*** Difference between total TiO_2 and soluble TiO2**

(A) represents an unclean, (B) a middle clean, (C) a clean rutile concentrate

The fine-grain structure of the minerals impedes separation; Extensive disaggregation and flotation become necessary. As flotation allows only to produce a 60 to 70 % TiO_2 concentrate, further separation techniques based on different magnetic and electrostatic properties as well as different densities of the minerals may be necessary to obtain a high TiO_2 rutile concentrate. Moreover, micro-agglomeration of the rutile concentrates will become obligatory; rutile concentrates of heavy mineral sand deposits have a size between 120 and 180 µ with a mean size of 160µ a large fraction of our rutile concentrates will have a size below 100 µm. (Dormann,1994). Engebofjellet deposit's is given in figure 5.2.

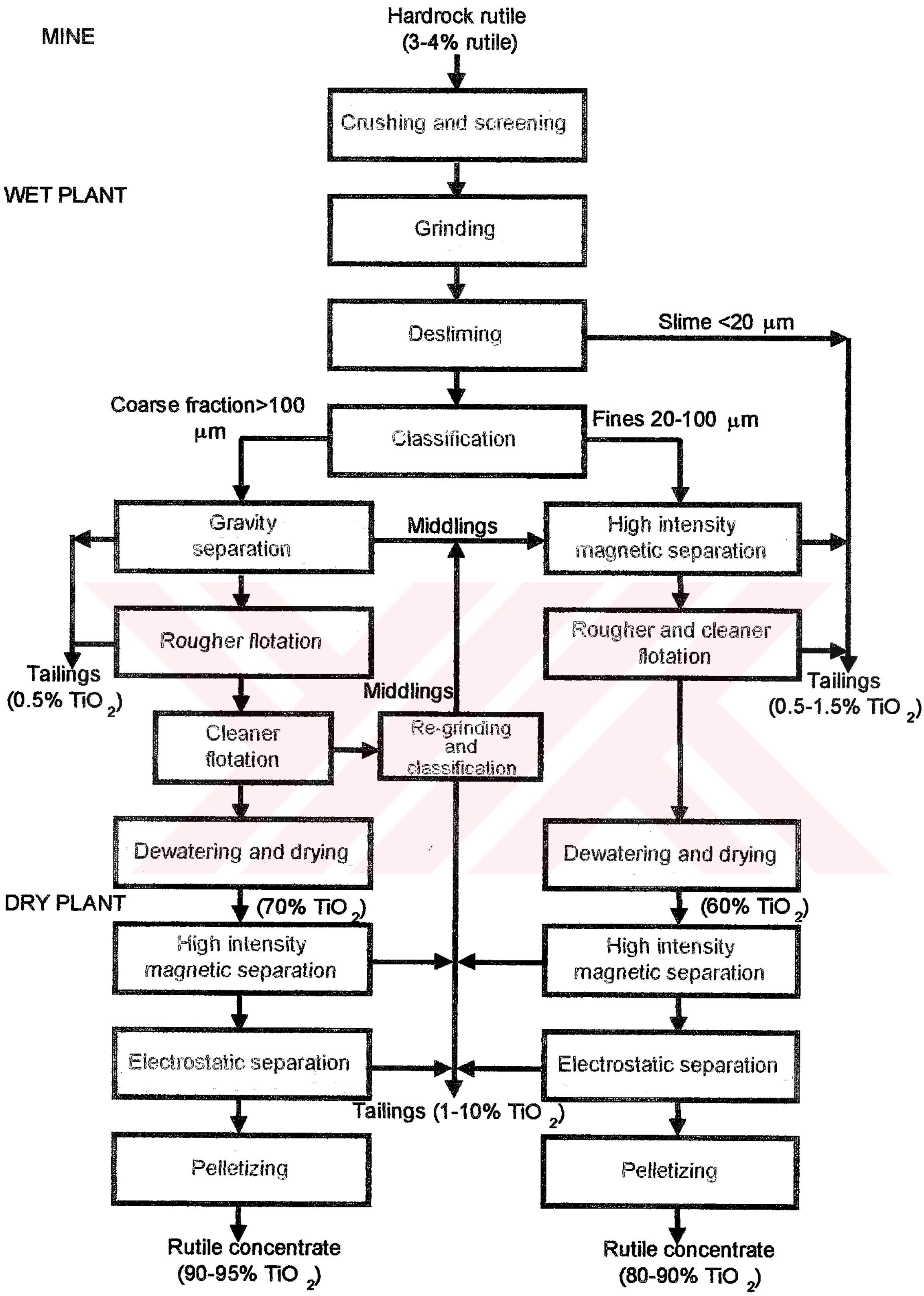

Figure 5.2 Primary processing of a hardrock rutile ore. (Dormann,1994),

5.2 Plant practice of feldspar

Feldspar processing depends on the nature of the deposit and on the demands of end application, as each application has it own specifications. The feldspar ore flotation system is one of the most complex practiced. The treatment of feldspar ores solely by flotation is a relatively recent development current flowsheets of mills operated by the feldspar Corp., Middletown, Conn; Del Monte Properties Co. at Pacific Grove, Calif; Amberger Kaolinwerke GmbH; and Esan Eczacıbaşı Industrial Raw Material Corp. in Turkey. Typically. the plant operations for separation of several feldspar minerals. Each plant operation is discussed in some detail with a flowsheet to show circuit details.

The Feldspar Corp. Middletown. Conn plant.: Typical practice is somewhat as follows:

➢ **Grinding and desliming:** Rod mill grinding to between 20 and 30 mesh. Desliming at about 200 mesh using classifier, hydroseparator or cyclone.

➢ **Mica flotation:** Conditioning at high-pulp density with sulfuric acid at a pH of 4 to5 and an amine salt and fuel oil. Addition of frother (pine oil) and flotation of mica. Flotation cleaning of mica in several stages if mica is marketable.

➢ **Basic silicate flotation (garnet, tourmaline, hornblende):** Dewatering and dereagentizing of nonfloat from mica flotation in classifier or cyclone. Conditioning at high pulp density with sulfuric acid at a pH of 3 to 4 with a long chain sulfonate-fuel oil mixture. Flotation of basic silicate in conjunction with a frother (pine-oil). Discard of float product from this stage.

➢ Feldspar flotation: Dewatering and dereagentizing: of the nonfloat frond basic flotation in classifier or cyclone. Conditioning at high-pulp density with hydrofluoric acid at pH of 2.5 to 3 with an amine salt-free oil mixture. Flotation of feldspar with a frother.

A simplified flowsheet of the process used at the Feldspar Corp. (Midleton, Conn.) plant is shown in figures 5.3. and 5.4.

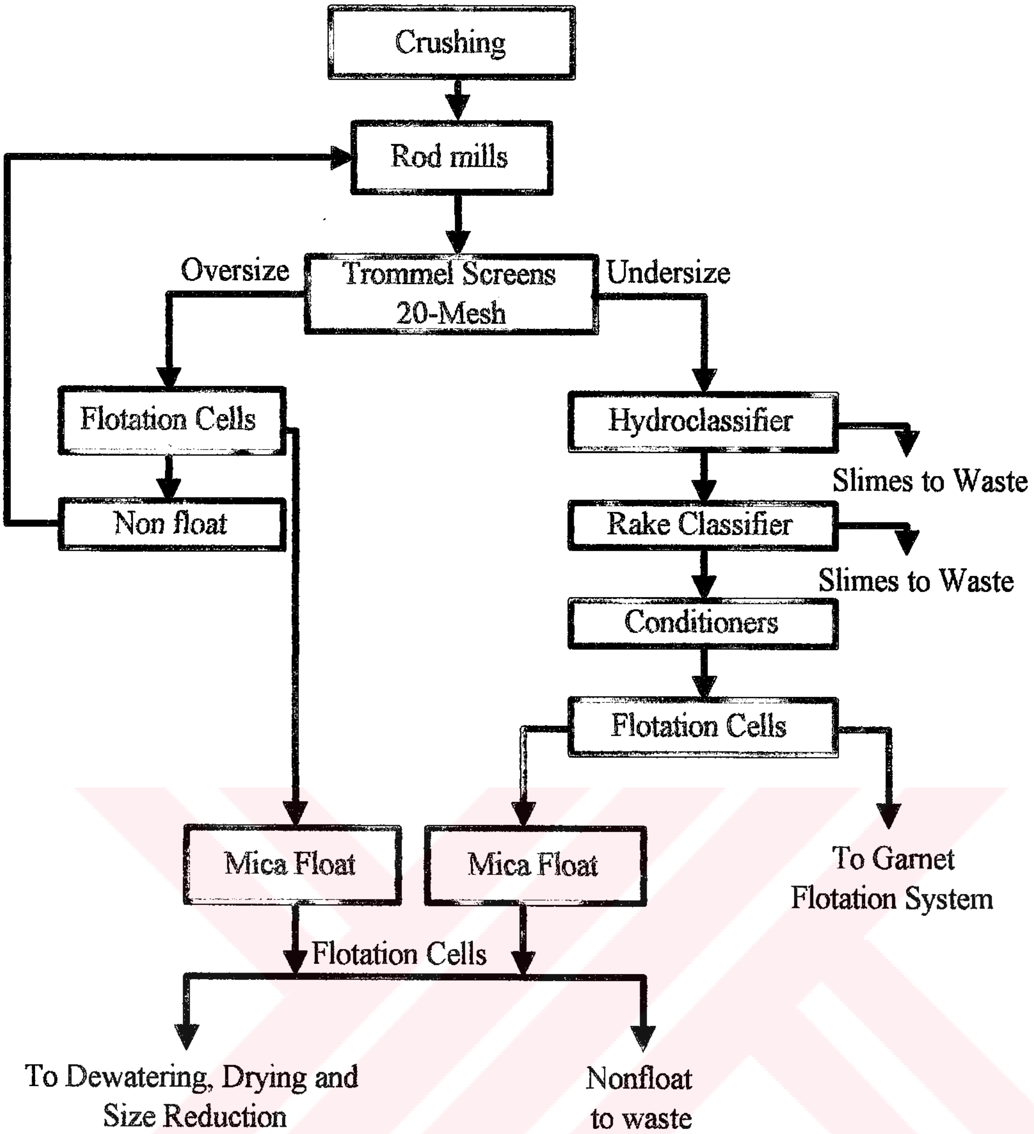

Figure 5.3 Size reduction and mica flotation, Feldspar Corp., Middletown, Conn., plant. (Rau,1986)

Table 5.2 Ore Composition and Mineral Recovery at the Feldspar Corp., Middletown, Conn,. Flotation Plant. (Rau,1986)

Mineral	Weight %	Recovered, % of original weight of ore
Feldspar	58	48
Quartz	33	25
Mica	7	3
Heavy minerals	2	-
Waste	-	24

The ores treated in this area contain 60 to 70 % feldspar, 25 to 30 % quartz, 3 to6 % muscovite, 2 % iron minerals, and minor amounts of clay. In some cases the nonfloat product from the feldspar flotation cells is screened to remove coarse feldspar ore reflected for removal of fine feldspar, thus increasing the production of a high-grade silica product suitable for glass manufacture.(Rau,1986).

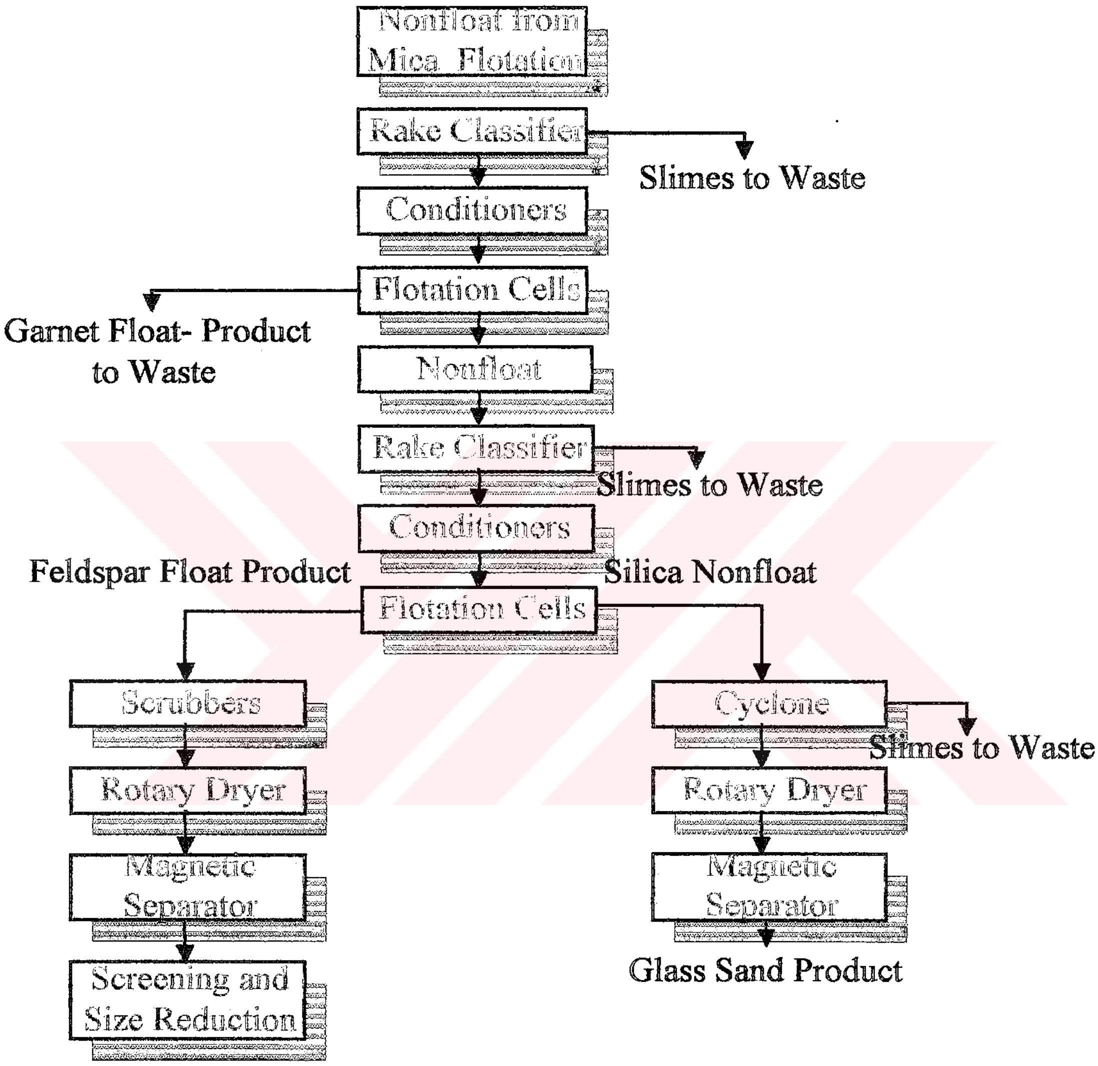

Figure 5.4 Garnet and Feldspar flotation, Feldspar Corp., Middetown, Conn., plant. (Rau,1986).

Amberger Kaolinwerke Eduard Kick GmbH (AKW): The location stands out due to its bordering on the primary rock formations of eastern and north-eastern Bavaria, which consist of granite and gneiss rich in feldspar and which were the source of across deposits that occur in a north-north-west direction. The feldspar content decreases from west to east within the 30-40 meter thick mine able layer of the Hirschau-Schaittenbacher Basin. The average values of the raw material in the western portion are whilst 6-12 % feldspar, 76- 78 % quartz and 10-14 % kaolin, in the east they are approximately 20 % kaolin and 80 % quartz. Kaolin predominates in the grain size fraction less that 20 μm and unweathered feldspar mainly in the grain size in order of 20-63 μm. The relationship of potassic-to-sodic-feldspar amounts to approximately 14:1 in the feldspar fraction. The maximum value of the distribution curve is found at 1mm for quartz.(Jakobs,1996)

The producers in processing of raw material into the end products feldspar, quartz and kaolin at the Hirschau plant is given in figure 5.5.

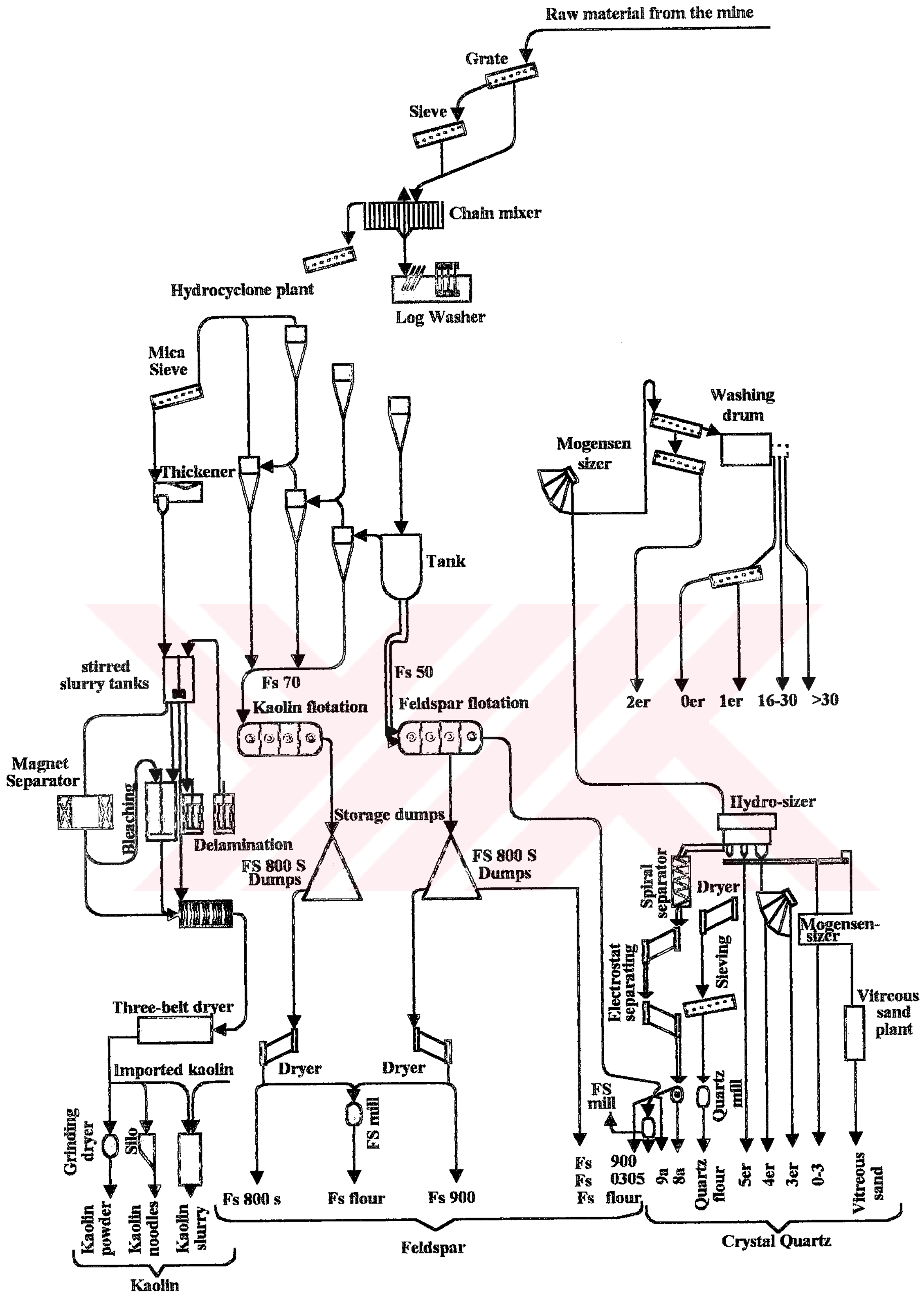

Figure 5.5 Processing installations of Amberger Kaolinwerke GMBH (Jakobs,1996).

Del Monte Properties Co: The ore treated at the Del Monte Properties Co. near Pacific Grove, Calif., is adune sand of granites origin containing about 50 % quartz and 50% feldspathic minerals, with approximately 0.2% heavy minerals content consisting of ilmenite, garnet, monazite and zircon. Flotation with sulfonate collectors is used to remove the heavy minerals. The resultant low-iron content sand may be either marketed as a mixed feldspar-silica product or sent to feldspar flotation to obtain separate low- iron content concentrates of feldspar and silica. The Del Monte plant are given in figure 5.6.

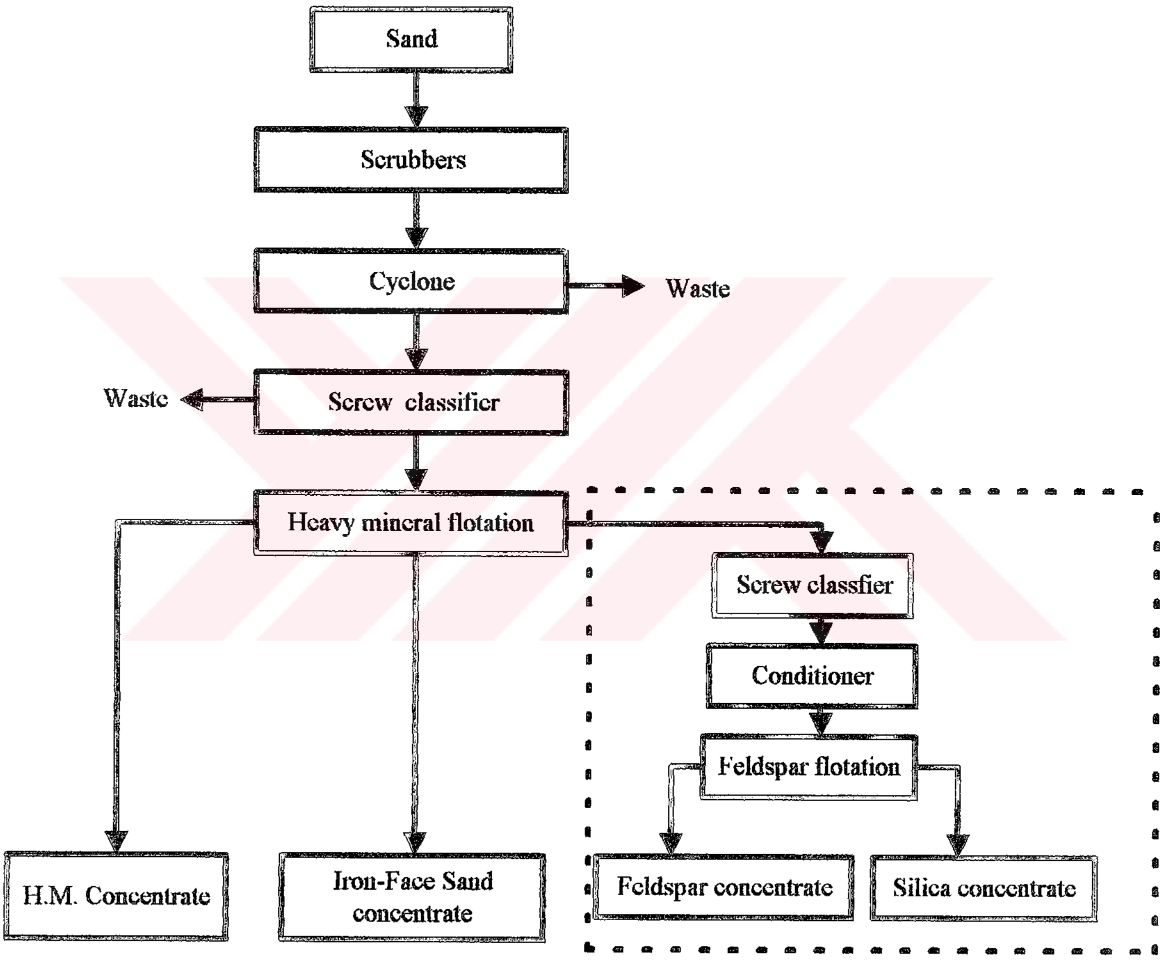

Figure 5.6 Flotation with sulfonate collectors, Del Monte Properties Co., Pacific Grove. (Lesure,1986).

An important feature of the successful separation of Del Monte sand is thorough attritioning of the particle surfaces to remove clay and hydrocarbon contamination. The sand is pulped and scrubbed in special attritioning machines at about 70% solids. Dilution water is added and the pulp is sent to cyclones for initial elimination of slimes. The cyclones under flow is sent to 20-mesh screen, from which a very small amount of 20-mesh sand is wasted and then to a screw classifier to complete the washing and desliming operation.

The screw-classifier discharge is conditioned in a drum conditioner at 65% solids in the presence of 0.5 lb. sulfuric acid, 0.8 lb. Reagent 801, 0.4 lb. Reagent 825, 0.4 lb. fuel oil and 0.005 lb. Aerofroth 65 per ton of feed. Flotation of the heavy minerals is carried out at pH 2.5 and the heavy mineral concentrate is sent to storage.

When separate feldspar and silica concentrates are desired, the tailings from the heavy mineral circuit are sent to a screw classifier for dewatering and are then conditioned in vertical conditioners at about 65% solids in the presence of 1.0 lb. hydrofluoric acid, 0.5 lb. Armac T(amine acetate); 0.25 lb. kerosene, and 0.1 lb. Aerofloth 65 per ton of feed. The feldspar is floated at pH 2.8. The feldspar concentrate and the feldspar circuit tailings(the silica concentrate) are dewatered, dried, and sent to storage.

Approximate chemical analyses of the concentrates produced are shown in Table 5.3.

Table 5.3 Chemical analyses of the concentrates produced at Del Monte Properties Co. (Lesure,1986).

Feldspar Concentrate		Silica Concentrate		Mixed Feldspar-Silica Product	
AL_2O_3	20%	SiO_2	98-99%	AL_2O_3	11.5%
Fe_2O_3	0.10%	AL_2O_3	0.1%	Fe_2O	0.06%
		Fe_2O	0.025%		

In China a pilot flotation installation has been set up on the basis of laboratory tests, its capacity is 1.5 t/day, and the flowsheet is shown in Figure 5.7.

The natural silica sand with NaOH is scrubbed in a rod mill, the discharge is sent to a spiral classifier for removal of NaOH and slime. The underflow with 60 % (by weight) solids is scrubbed under high density in a scrubber, and then stripped of NaOH and slime again in a hydroclassifier. The underflow from hydroclassifier with about 55 % solids is mixed with the collector in a conditioning tank and strongly stirred under high density. The resulting pulp is diluted to about 25 % solids and fed to a flotation machine for aerated flotation.(Jıaying,Jufan,Baogı,1988)

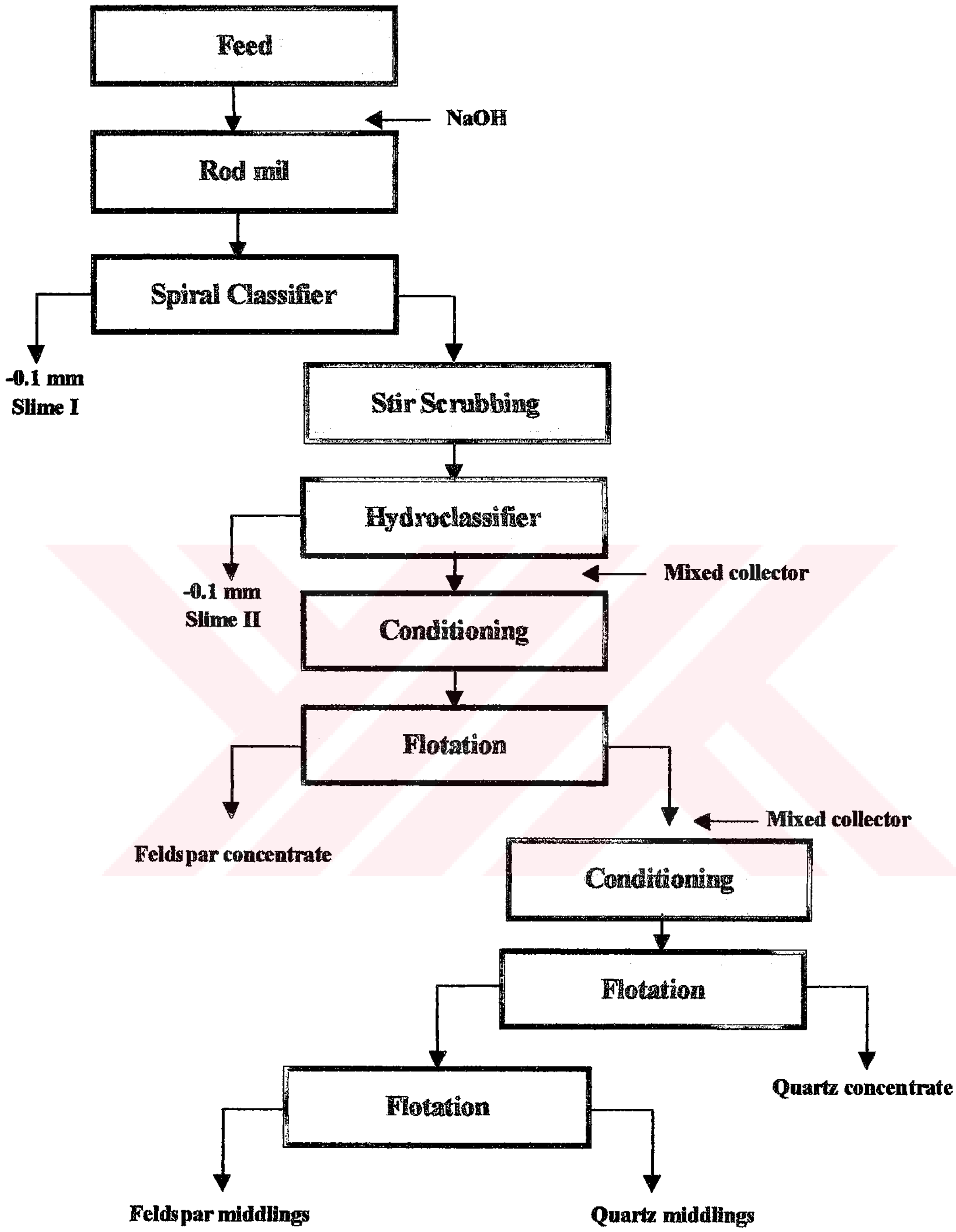

Figure 5.7. Flowsheet of continuous flotation.(Jiaying,Jufan,Baogı,1988).

Esan Eczacıbaşı Industrial Raw Material Corp: Esan Eczacıbaşı Industrial Raw Material Corp. in Turkey has large feldspar concessions in the Milas area and has the capacity to produce 200.000 tpa crude sodium feldspar and 5.000-10.000 tpa capacity to produce 200.000 tpa crude sodium feldspar and 5.000-10.000 tpa potassium feldspar. At present the company is exploiting the most accessible deposits closets to the port of Güllük. The deposits are fairly consistent, containing 9-10% Na_2O.By selective mining, the company produces two grades from a crushing plant at the mines. Standard grade Na- feldspar containing 0.1% Fe_2O_3 and0.03% TiO_2, fires to a yellow color, While a higher grade, white firing product contains.0.08 % Fe_2O_3 and 0.02 % TiO_2.

Esan also operated a 15.000tpa dry grinding plant at Milas along with a flotation circuit. Three floated grades of Na-feldspar are produced from –500 µm feed a glass grade -500µ+100 µm, a fret grade -100µm, and a high whiteness grade. The high whiteness grade contains less than 0.04 % Fe_2O_3 and 0.05 % TiO_2 after flotation to remove rutile Figure 5.8 shows the flowsheet of Milas Albite Flotation Plant.

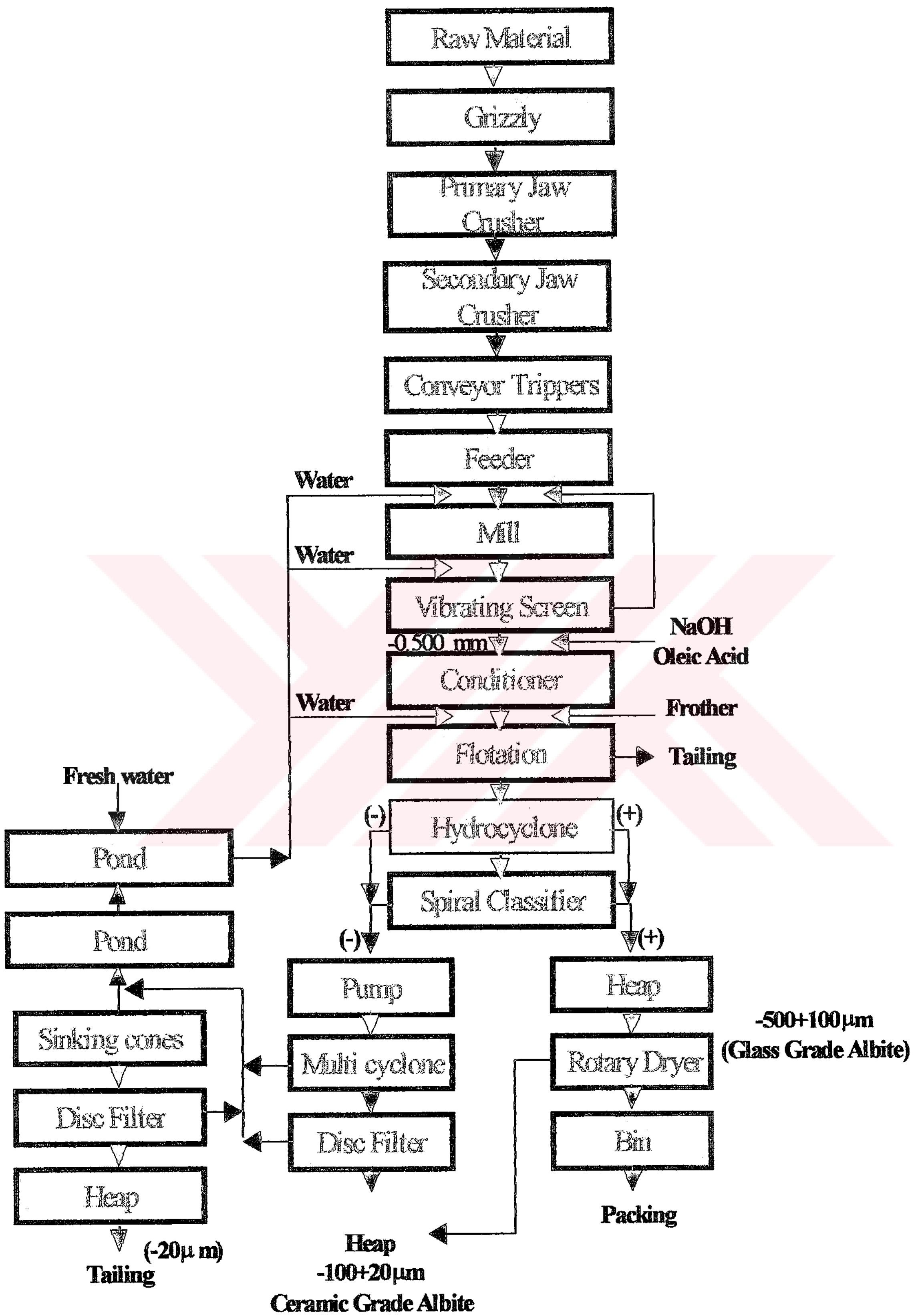

Figure 5.8 Flowsheet of Milas albite flotation plant.

CHAPTER SIX
EXPERIMENTS

6.Experiments

6.1 Experiments Studies of Titanium Eclogite Ore

The representative sample was taken from Ödemiş-Kiraz region.As seen figure 6.1. The samples were collected from each points and mixed to about 160 kg. A basic method of flotation was devised, the results of the beneficiation studies. After that, the samples were crushed and ground in order to prepared for test and recovery experiments. Using this method, preliminary flotation tests were conducted in a Denver laboratory type flotation machine. Pulp density was about 25-30 pct solids, unless specifically stated otherwise. Chemical composition of Ödemiş-Kiraz eclogite is given in table6.1.

Table 6.1 Chemical analysis results of Ödemiş- Kiraz titanium eclogite

Fe_2O_3 %	TiO_2 %	SiO_2 %	Al_2O_3 %	CaO %	MgO %	K_2O %	Na_2O %
19.59	1.68	48.79	14.29	8.43	3.59	0.69	2.94

6.1.1 Preparation of the sample

As the sample from Ödemiş-Kiraz was selectively and gradually crushed to minor 4mm by laboratory type primary and secondary jaw crushers. The sample under 1 mm was subjected to sieve analysis, as a part of final crushing the materials crushed to minus by a ball crusher. The flowsheet of sample preparation is given in figure 6.2. Figure 6.3. presents under size curves of the final crushed sample.

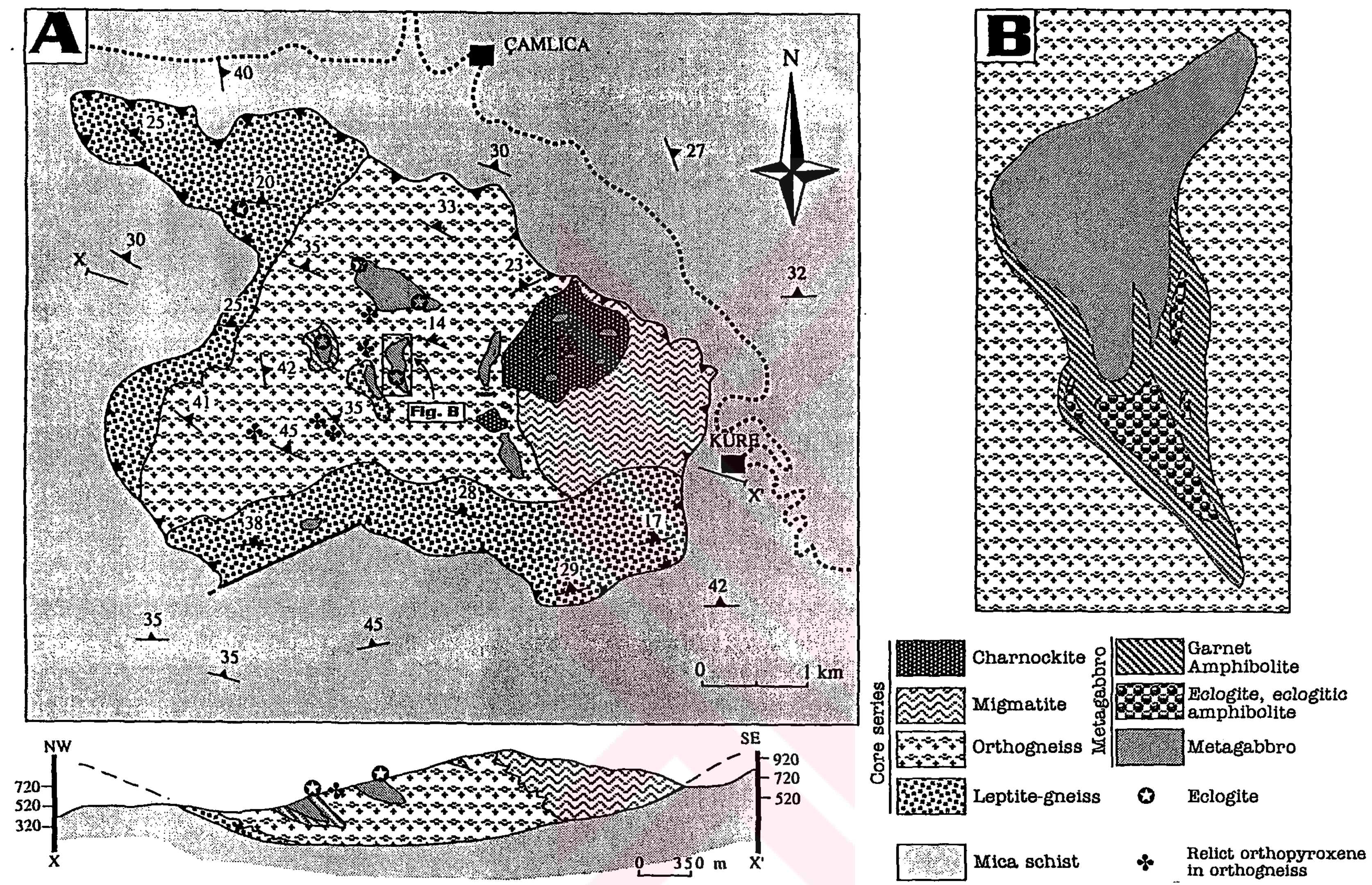

Figure 6.1 It was seen Titanium Eclogite Ore from Ödemiş-Kiraz region.

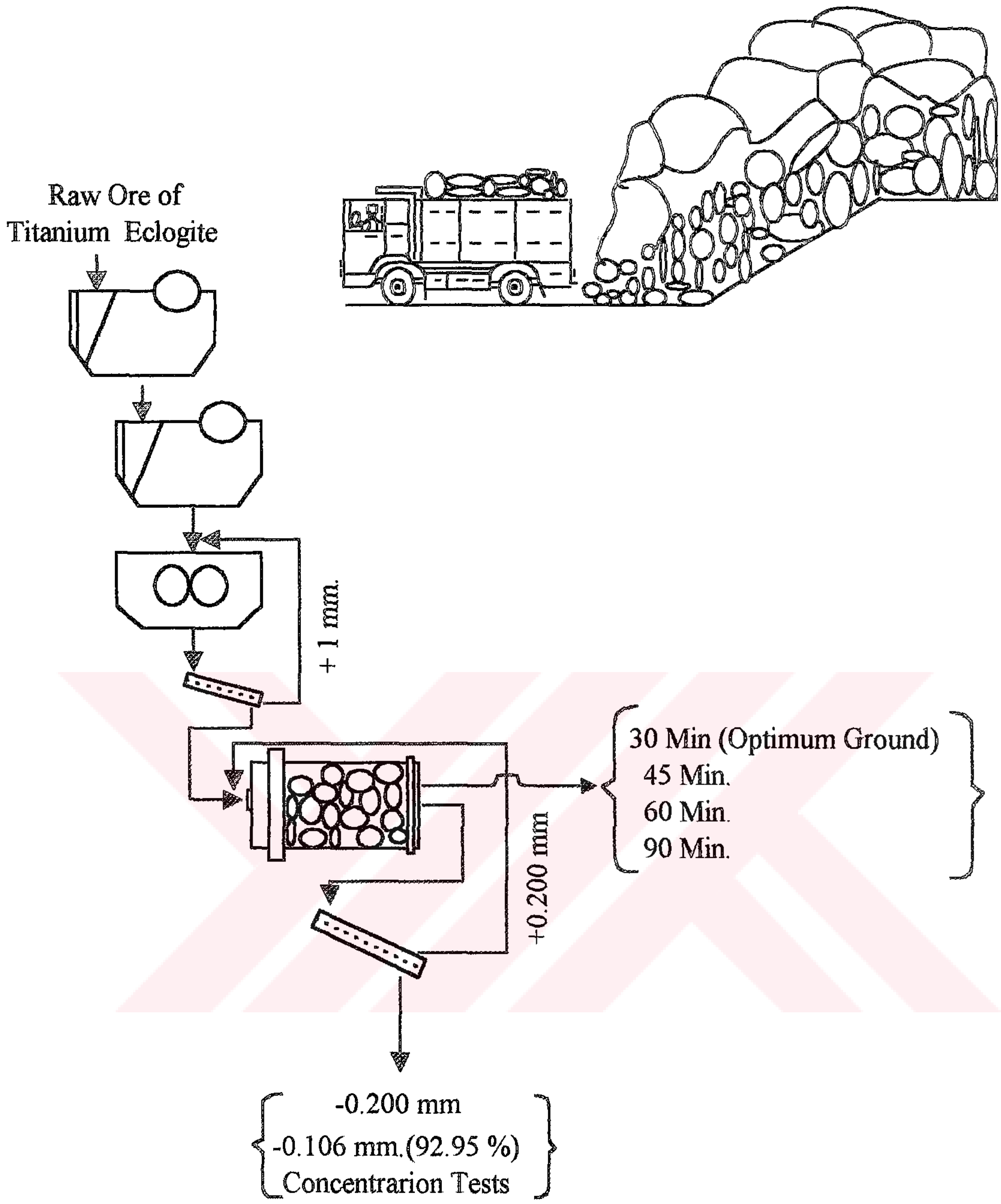

Figure 6.2. A flowsheet developed for the mineral processing of Tire-Ödemiş Titanium Eclogite Ore.

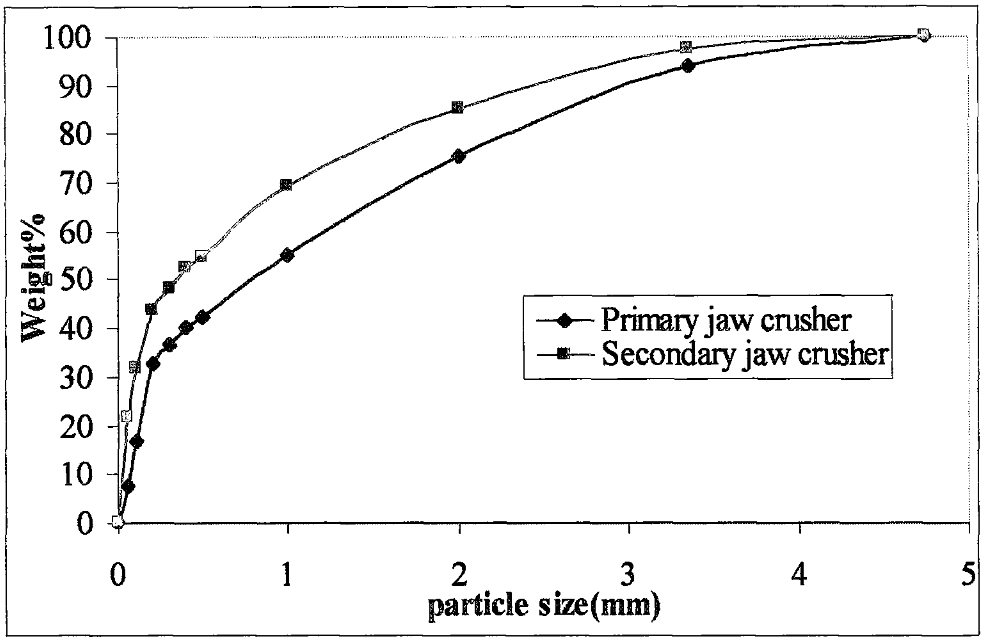

Figure 6.3 Undersize curves of crushed ore.

Crushed materials were ground by a laboratory type ball mill and controlled by sieve in a regular time. The ball mill charge was 1.000 g. of ore and 8.000 g of ball as a grinding media. So the relation between grinding time and particle size were determined from these tests. The microscopic studies showed that the sample had to be ground to minus 106 μm to achieve a significant degree of liberation with 30 minutes of grinding. Size distribution of ground ore presents in table 6.2. and figure 6.3.

Table 6.2 Size distribution of ground ore in different time period.

Size (mm)	30 min.	45 min.	60 min.	90 min.
	ΣU,Size	ΣU,Size	ΣU,Size	ΣU,Size
-0,20+0,106	100,00	100,00	100,00	100,00
-0,106+0,063	92,95	97,45	98,27	99,17
-0,063+0,038	67,46	69,53	68,83	49,96
-0,038+0,00	29,33	28,69	15,24	6,38

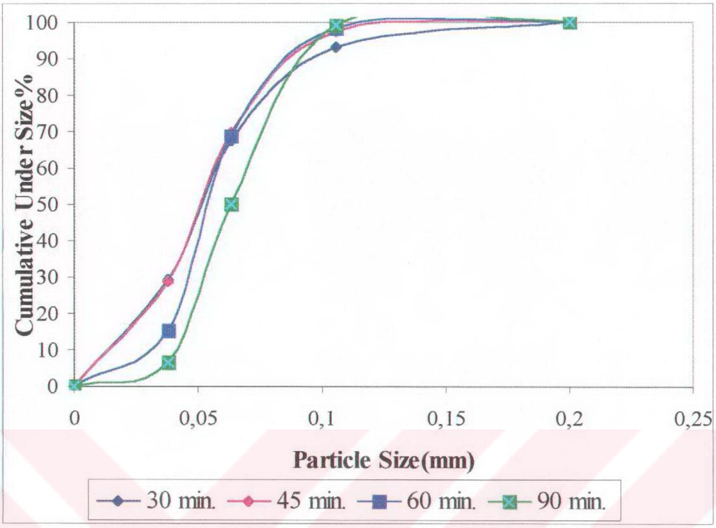

Figure 6.4 Cumulative undersize in different time periods.

6.2 Experiments Studies of Aydın-Çine Feldspar

The representative sample was taken from Aydın- Çine region. The samples were collected from each points and mixed to about 100kg. A basic method of flotation was devised, the results of the beneficiation studies. After that, the samples were crushed and ground in order to prepared for test and recovery experiments. Using this method, preliminary flotation tests were conducted in a Denver laboratory type flotation machine. Pulp density was about 25-30 pct solids, unless specifically stated otherwise.

6.2.1 Preparation for the sample

As the sample from Aydın- Çine was selectively and gradually crushed to 4mm by laboratory type primary and secondary jaw crushers. The sample under 1 mm was subjected to sieve analysis, as a part of final crushing the materials crushed to minus by a impact crusher. The flowsheet of sample preparation is given in figure 6.5. Figure 6.6. presents under size curves of the final crushed sample.

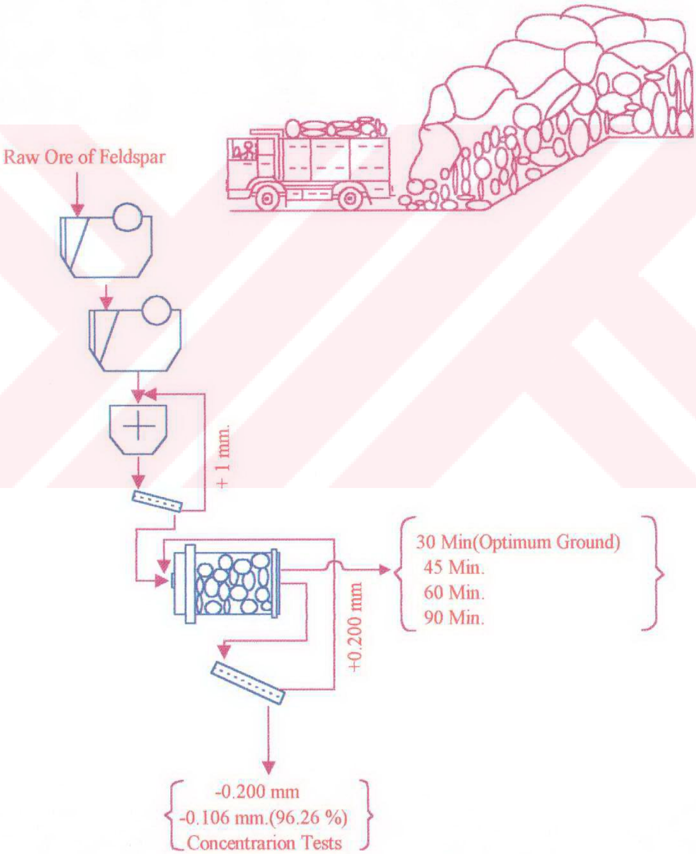

Figure 6.5 Flowsheet of sample preparation of Titanium Eclogite Ore.

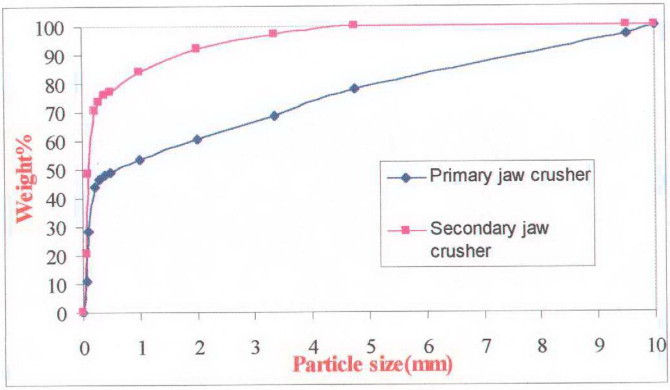

Figure 6.6 Undersize curves of crushed ore.

Crushing materials were ground by a laboratory type ball mill and controlled by sieve in a regular time. The ball mill charge was 1.000 g. of ore and 8.000 g of ball as a grinding media. So the relation between grinding time and particle size were determined from these tests. The microscopic studies showed that the sample had to be ground to minus 106 μm to achieve a significant degree of liberation with 30 minutes of grinding. Size distribution of ground ore presents in table 6.3. and figure 6.7.

Table 6.3 Size distribution of ground ore in different time period.

Size(mm)	15 min.	30 min.	45 min.	60 min.	90 min.
	ΣU,Size	ΣU,Size	ΣU,Size	ΣU,Size	ΣU,Size
-0,250+0,212	100,00	100,00	100,00	100,00	100,00
-0,212+0,106	99,37	100,00	100,00	100,00	100,00
-0,106+0,063	86,81	96,26	98,92	100,00	100,00
0,063+0,053	48,21	67,27	67,04	74,36	75,39
-0,053+0,038	34,40	48,67	46,37	59,77	66,52
-0,038+0,00	17,05	13,35	7,29	13,35	15,78

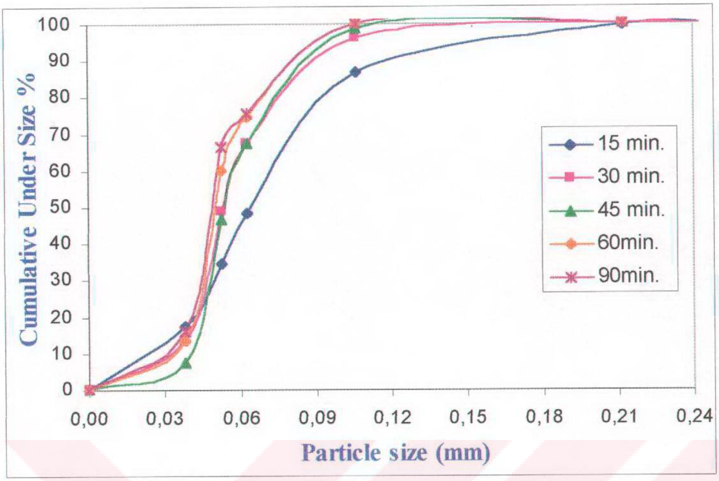

Figure 6.7 Cumulative undersize in different time periods.

6.3 Beneficiation of Titanium Eclogite by Multi Gravity Separator (MGS)

With the MGS separation is obtained through the combined action of centrifugal force provided by the rotation of a drum and the force provided by shakes of variable amplitude and frequency. There are three main parameters of the MGS; There are speed of rotation, shake frequency and shake amplitude. MGS is shown in figure 6.8.

Figure 6.8 Multi Gravity Separator (MGS)-Laboratory Type.

The ore, which was crushed under 1 mm by roll crusher and ground to minor 106 μm .(%92.95). After, MGS experiment carried out for determination of the MGS machine parameters. In this experiment; before experimental study, we did literature investigation in order to best concentration of titanium eclogite . All concentrates of MGS was passed through wet magnetic separator at 10.000 gauss. The aim of using magnetic separation was to remove iron content from the titanium eclogite.

Results of MGS are given in table 6.4.The flowsheet of the determination for the recovery of concentrate from titanium ore was given in figure 6.9. Experiment conditions used was under the following operating conditions :

Rotation Speed : 180 rpm

Water Supply : 3.5 lt./min.

Tilt : 4°

Feed Rate : 30 kg./h.

Solid Concentration :30 % Solids

Table 6.4. Results of MGS

Products	Weight	Grade (%)				Recovery (%)			
	(%)	SiO_2	Fe_2O_3	TiO_2	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	Al_2O_3
Concentre	62,56	54,82	16,50	5,08	13,68	70,06	54,33	97,19	59,89
Tailing	37,44	39,14	23,18	0,25	15,31	29,94	45,67	2,81	40,11
Total	100,00	48,95	19,00	3,27	14,29	100,00	100,00	100,00	100,00

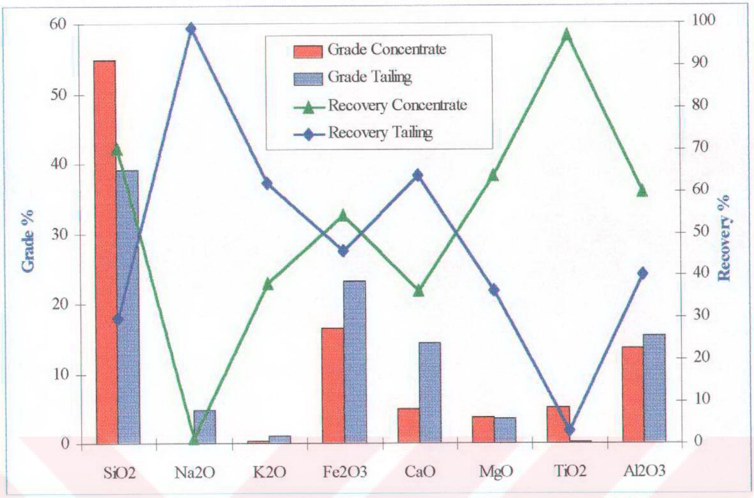

Figure 6.9. Change of elements of grade and recovery (MGS).

As you can see in the figure 6.9. TiO_2 grade increased 3.27 % at raw ore from 5.08 % at concentrate of MGS. Tailing of titanium eclogite grade was lowest value at 0.25 %. Al_2O_3 and Fe_2O_3 grade decreased from 14.29 %,19.00 % at raw ore to 13.68 %. 16.50 % at concentrate. However, SiO_2 grade increased from 48.95 % to 54.82 %.The flowsheet of Titanium Eclogite is shown in figure 6.10.

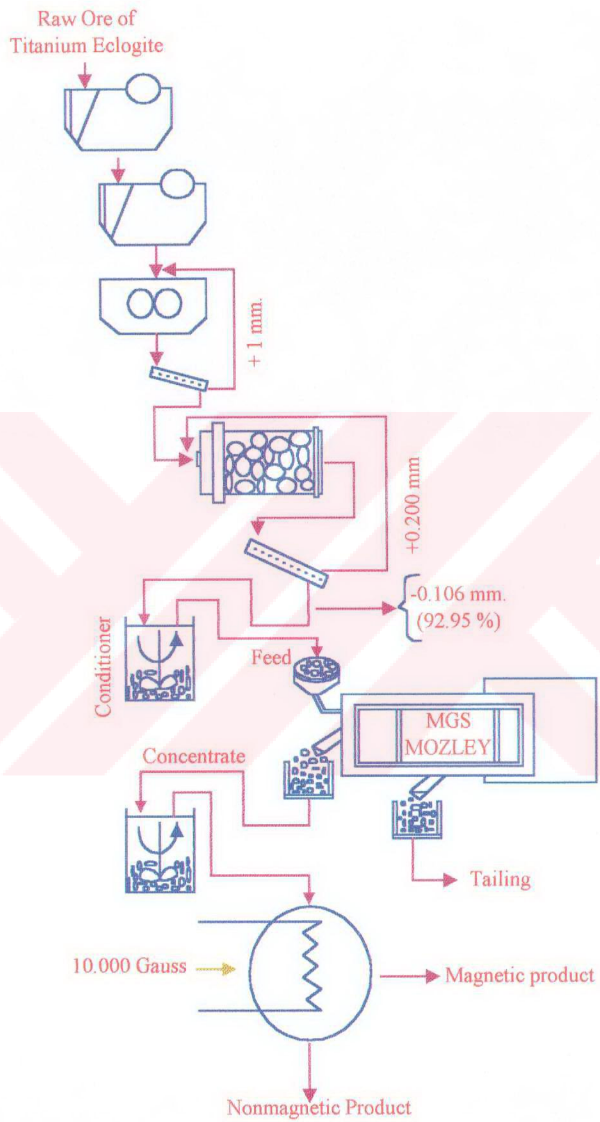

Figure 6.10 Flowsheet of recovery of concentrate from Tiataniom Eclogite Ore.

6.4 Wet Tabling of Titanium Eclogite Ore

This process is to remove all the light from heavy minerals. In this study, titanium eclogite that crushed minor 1 mm by roll crusher. After, In order to determine optimum particle size each wet tabling test was performed at four different particle size distributions. These are "–0.5 + 0.3" mm, -"0.3 +0.2" mm, -"0.2 + 0.1"mm, -"0.1 + 0.063" mm. All concentrates of wet tabling was passed through wet magnetic separator at 10.000 gauss. The aim of using magnetic separation was the remove iron content of the titanium eclogite. The result of the Wet Tabling Tests are given in table 6.5. Flowsheet of Wet Tabling enrichment was given in figure 6.15.

Table 6.5 Results of Wet Tabling Enrichment.

Particle Size	Products	Weight	Grade (%)				Recovery (%)			
(mm)		(%)	SiO_2	Fe_2O_3	TiO_2	Al_2O_3	SiO_2	Fe_2O3	TiO_2	Al_2O_3
-0,5+0,3	Concentrate	45,85	69,37	10,78	4,21	16,55	64,98	26,01	59,03	53,10
	Tailing	54,15	31,66	25,96	2,47	12,38	35,02	73,99	40,97	46,90
	Total	100,00	48,95	19,00	3,27	14,29	100,00	100,00	100,00	100,00
-0,3+0,2.	Concentrate	59,65	47,96	18,02	5,26	16,55	58,44	56,57	95,95	69,08
	Tailing	40,35	50,41	20,45	0,33	10,95	41,56	43,43	4,05	30,92
	Total	100,00	48,95	19,00	3,27	14,29	100,00	100,00	100,00	100,00
-0,2+0,1	Concentrate	37,59	45,21	20,08	6,42	15,37	34,72	39,73	73,80	40,43
	Tailing	62,41	51,20	18,35	1,37	13,64	65,28	60,27	26,20	59,57
	Total	100,00	48,95	19,00	3,27	14,29	100,00	100,00	100,00	100,00
-0,1+0,063	Concentrate	42,80	59,04	13,17	7,56	13,21	51,62	29,67	98,95	39,57
	Tailing	57,20	41,40	23,36	0,06	15,10	48,38	70,33	1,05	60,43
	Total	100,00	48,95	19,00	3,27	14,29	100,00	100,00	100,00	100,00

Experiment conditions was given as follow;

Pulp density : 30 % Solids

Amplitude :10-25 mm.

Tilt : 1/48 –1/24

Speed : 240-325strock/min.

The changes in size distribution obviously affect TiO_2 and Al_2O_3 grades of titanium concentrate. As you can be seen in figure 6.11, 6.12, 6.13,and 6.14. While particle size decreased TiO_2 grade, increased from 4.21 % at –"0.5+0.3" mm. to 7.56 % at –"0.1+0.063"mm. moreover, TiO_2 recovery increased from 59.03 % to 98.95 %. Incidentally, Al_2O_3 grade and recovery decreased from 16.55 % to 13.21 % and 53.10 % to 39.57 %. In addition, Fe_2O_3 grade and recovery decreased, from 16.50 %, 54.33 % to 13.17 %, 29.67 % at this particle size distribution.

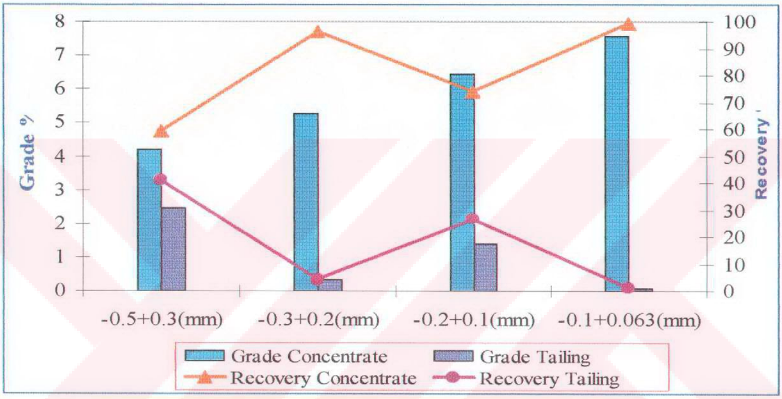

Figure 6.11. Change of TiO_2 in concentrate and tailing.

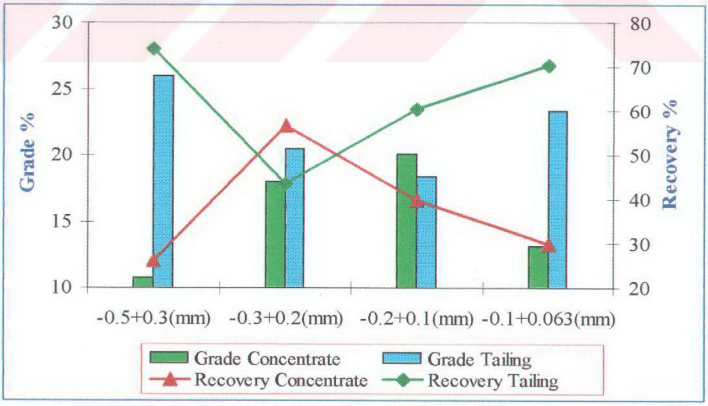

Figure 6.12 Change of Fe_2O_3 in concentrate and tailing.

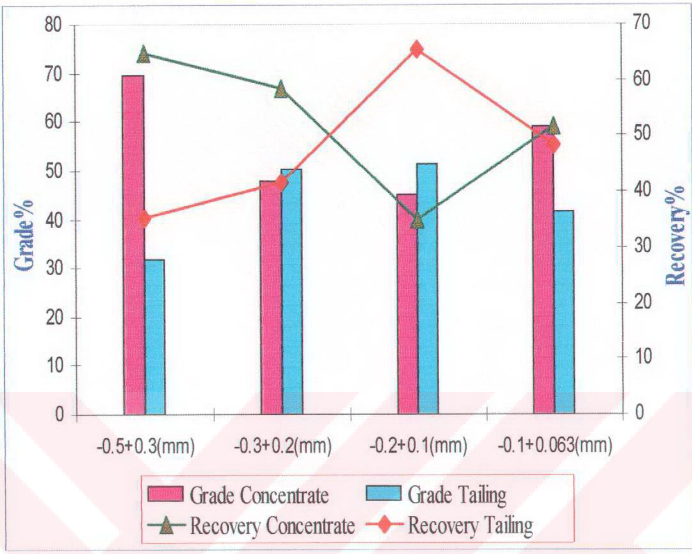

Figure 6.13 Change of SiO_2 in concentrate and tailing

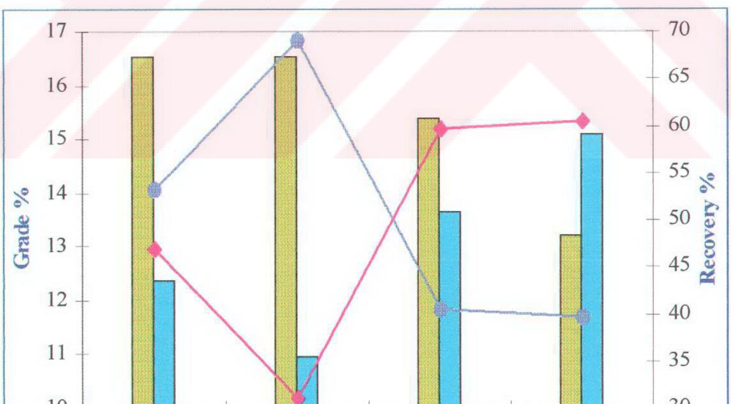

Figure 6.14 Change of Al_2O_3 in concentrate and tailing

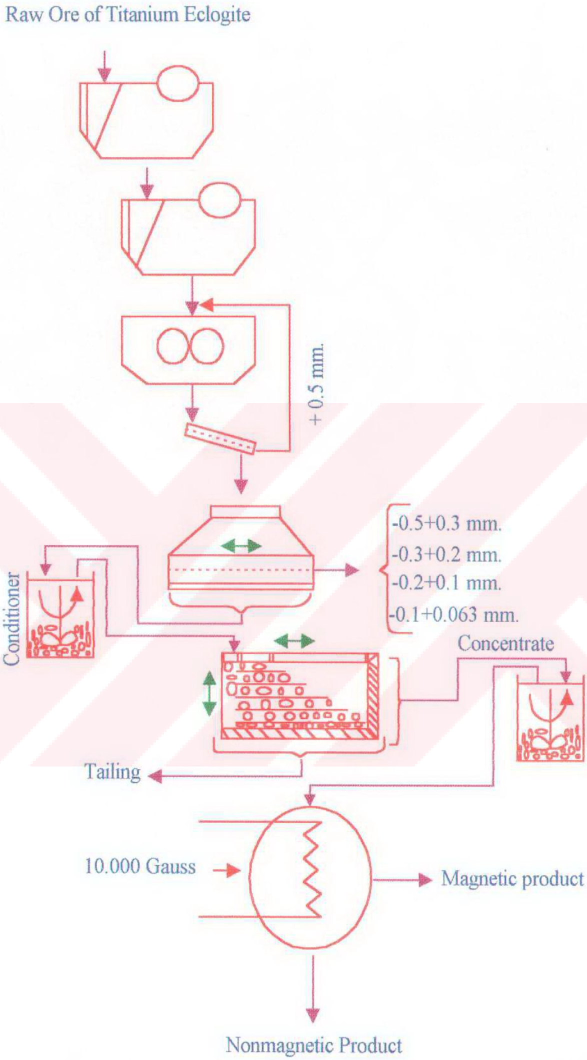

Figure 6.15 Flowsheet of recovery of concentrate from Tiatanium Eclogite Ore.

6.5 Flotation Experiments of Titanium Eclogite

Flotation parameters were investigated to observe the behavior of titanium on flotation. During all the flotation tests the particle size distribution (-106 μm 92.95 %), conditioning at 50-60 % pulp density, pH 2.5-3, and impeller speed (1400 rpm) were stable and all the other parameters were variables. Moreover, the flotation experiments were carried out in a Denver type laboratory flotation machine with 2 liter cell.

6.5.1 Ph Tests of Titanium Eclogite

Investigation of the effect of pH change on feldspar and rutile flotation was the object of these tests. The conditions and tested values of pH are as follows:

Slime:

Dowfroth 1012 : 50 g/t.

Condition :10 min.

Mica:

Ph :3,5,neutral,9,12 with H_2SO_4

Armac T :400 g/t.

Fuel Oil Burning Oil : 400g/t.

Dowfroth 1012 :30 g/t.

Condition :10 min.

Basic Flotation:

Ph :3,5,neutral,9,12 with H_2SO_4

Aero 801 :300 g/t

Aero 825 :600 g/t

Fuel Oil + Burning Oil : 300 g/t.

Dowfroth 1012 : 100 g/t.

Condition : 10 min.

As it can be seen in figure 6.16 and 6.17. While pH increased; TiO_2 and Fe_2O_3 grade decreased from 3.87 %,14.45 % at pH 3 to 2.09 % , 13.12 % at pH 12. In this pH range; TiO_2 and Fe_2O_3 recovery decreased from 44.95 %.17.46 % to 18.06 %,11.61 %. In figure 6.18. From pH 3 to 9; SiO_2 grade and recovery decreased from 80.50 %,17.35 % to 72.85 %, 14.86 % but, at pH 12 grade increased 79.33 %., recovery did not change. As you can see at this pH range Al_2O_3 grade and recovery increased from 6.81 %, 11.00 % at pH 3 to16.5 %, 19.09 % at pH 12. The recovery and grade reached its highest value at pH 3, because rutile and iron oxides can be floated in this pH range. The result of the pH tests are given in table 6.6.

Table 6.6 Titanium Eclogite flotation at different pH values

Ph Tests	Products	Weight %	Grade %				Recovery %			
			Fe_2O_3	TiO_2	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	SiO_2	Al_2O_3
Ph=3	Slime	8,25	13,81	0,90	89,44	16,50	7,64	4,79	8,83	12,19
	Mica	7,80	13,64	0,87	92,45	18,65	7,13	4,37	8,63	13,03
	Concentrate	18,02	14,45	3,87	80,50	6,81	17,46	44,95	17,35	11,00
	Tailing	65,93	15,33	1,08	82,68	10,8	67,77	45,89	65,20	63,78
	Feed	100,00	14,92	1,55	83,61	11,16	100,00	100,00	100,00	100,00
Ph=5	Slime	7,33	13,50	0,95	87,99	21,53	6,63	3,74	7,73	12,51
	Mica	9,47	12,76	0,89	97,79	20,18	8,10	4,52	11,11	15,15
	Concentrate	15,06	14,14	2,85	82,45	18,78	14,27	23,02	14,89	22,41
	Tailing	68,14	15,54	1,88	81,09	9,25	70,99	68,72	66,26	49,93
	Feed	100,00	14,92	1,86	83,39	12,62	100,00	100,00	100,00	100,00
Ph=7	Slime	13,41	13,60	1,12	83,07	19,06	12,10	8,05	14,08	16,65
	Mica	13,07	12,45	0,94	93,12	21,69	10,80	6,59	15,39	18,46
	Concentrate	13,76	13,96	2,45	72,53	18,98	12,74	18,07	12,62	17,01
	Tailing	59,76	16,23	2,10	76,63	12,3	64,35	67,29	57,91	47,88
	Feed	100,00	15,07	1,87	79,09	15,35	100,00	100,00	100,00	100,00
Ph=9	Slime	19,25	13,55	1,45	71,00	25,17	17,86	16,45	19,36	28,81
	Mica	11,02	12,22	1,30	78,73	28,51	9,23	8,42	12,29	18,69
	Concentrate	14,40	12,83	2,36	72,85	18,23	12,66	20,01	14,86	15,62
	Tailing	55,34	15,34	1,69	68,21	11,20	58,14	55,12	53,48	36,88
	Feed	100,00	14,60	1,70	70,58	16,81	100,00	100,00	100,00	100,00
Ph=12	Slime	25,31	13,35	1,22	91,25	19,8	22,92	20,43	32,80	44,48
	Mica	4,51	12,83	1,10	89,64	24,50	3,92	3,28	5,74	9,79
	Concentrate	13,05	13,12	2,09	79,33	16,5	11,61	18,06	14,71	19,09
	Tailing	57,13	15,89	1,54	57,61	5,26	61,55	58,23	46,75	26,63
	Feed	100,00	14,75	1,51	70,41	11,28	100,00	100,00	100,00	100,00

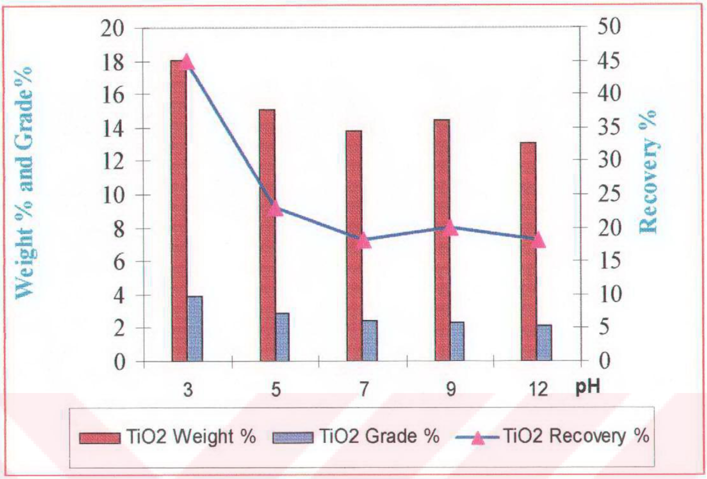

Figure 6.16 Effect of pH change for Titanium ore on flotation

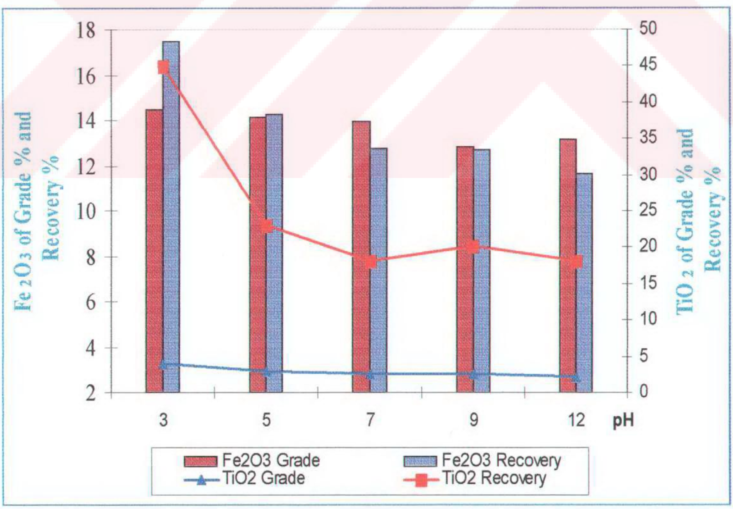

Figure 6.17 Effect of pH change of TiO_2 and Fe_2O_3 in concentrate

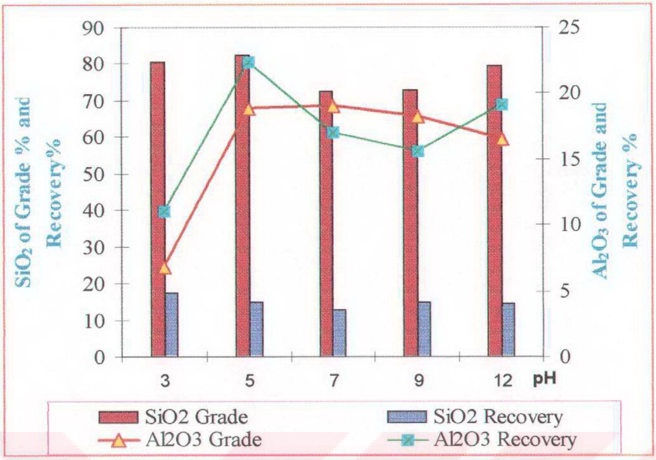

Figure 6.18 Effect of pH change of SiO_2 and Al_2O_3 in concentrate.

6.5.2 Flotation Tests

The titanium eclogite flotation system is one of the most complex practiced . Study of flotation was operated with three step. Typical practice is shown under the following operating conditions;

❖ Desliming at about minus 37 μm using Dowfroth 1012. Desliming always was done as do like these operations.

❖ Conditioning at high pulp density with H_2SO_4 at a pH 2.5-3 with Fuel Oil + Burning Oil mixture after this, additional of frother (Armac T) and flotation of mica.

❖ Dewatering of the nonfloat from mica flotation and conditioning at high pulp density with H_2SO_4 at a pH 2.5-3 with Aero series after that, additional of Fuel Oil Burning Oil and frother. (Armac T).

In third step, Basic flotation is given heavy mineral product (TiO_2,Fe_2O_3 include). This flotation system, Rougher titanium concentrates are usually a satisfactory final product, but floatation cleaning may be cleaned in order to clean titanium.

As a heavy mineral, recovery of rutile was aimed with heavy mineral flotation by floating rutile and iron oxides.

The results of experiments were evaluated utilizing x-ray spectrometer, by using the standards, the grades of that had been determined by chemical analysis. The result s of the flotation experiments are presented in table 6.7. An illustration of the flowsheet of flotation with wet magnetic separator is presented in figure 6.23 and 6.24.

As it can be seen in figure 6.19. At experiment 5; the sample was passed through wet magnetic separator at 5000 gauss. After, the magnetic and non magnetic product was fed in to the flotation process. The aim of using magnetic separation was to remove iron concent of the ore. The results in table 6.7. and Figure 6.19. pointed out that combination of flotation with magnetic separation provided that the most satisfactory TiO_2 grade was 4.10 %. An illustration of the flowsheet of flotation is presented in figure 6.25 and 26.

At experiment 6; TiO_2 grade decreased from 4.10 % to 3.81 %, but recovery of TiO_2 increased from 37.44 % to 52.88 % at this experiment range. However, external of enrichment, there was no important difference between combination of flotation with wet magnetic separator and direct flotation. The results of flotation with magnetic separator were presented in figure 6.19, 6.20, 6.21, 6.22.

As it can be seen in table 6.7; experiment 4 differs experiment 3 it has more TiO_2 grade 3.10 % . Because salt washer provided the clean of iron surface and result of this, increased TiO_2 grade and incidentally recovery from 3.02 %, 22.70 % at not using salt washer to 3.10 % , 57.32 % at combination of flotation with salt washer. On the other hand; while flotation of ore by using of salt washer was decreased Fe_2O_3 grade from 19.49 % to 17.55 %.

To comparison with experiment 1 and experiment 2; experiment 1 has more recovery. Because, The flotation with Aero 853 is in creased of concentrate amount.

Experiment	Products	Weight	Grade %				Recovery %			
Parameters:		%	Fe_2O_3	TiO_2	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	SiO_2	Al_2O_3
No:1	Slime	2,38	15,51	1,02	82,55	20,05	1,98	1,07	3,24	4,46
Aero 801	Mica	3,93	14,43	0,58	1,67	16,59	3,05	1,00	0,11	6,09
Aero 853	Middling	5,00	12,99	1,67	93,95	2,50	3,49	3,67	7,75	1,17
Na_2SiO_3	Concentrate	43,69	18,37	2,88	62,94	12,70	43,11	55,14	45,39	51,85
Fuel Oil	Tailing	45,00	20,01	1,98	58,58	8,67	48,37	39,13	43,51	36,44
Burning Oil	Feed	100,00	18,62	2,28	60,58	10,70	100,00	100,00	100,00	100,00
No:2	Slime	2,34	15,85	1,25	79,69	22,22	2,35	1,47	2,28	4,06
Aero 801+851	Mica	4,21	14,27	1,31	84,93	13,42	3,81	2,77	4,38	4,41
Na_2SiO_3	Concentrate	23,46	19,71	3,20	55,69	29,25	29,32	37,67	16,02	53,56
Fuel Oil	Tailing	70,00	14,53	1,79	90,06	6,95	64,51	58,09	77,31	37,98
Burning Oil	Feed	100,00	15,77	1,99	81,55	12,81	100,00	100,00	100,00	100,00
No:3	Slime	1,58	15,18	0,92	74,54	22,58	1,21	1,23	2,22	4,11
Aero 801	Mica	3,66	14,12	0,85	90,78	10,67	2,61	2,62	6,26	4,50
Aero 727	Concentrate	8,94	19,49	3,02	52,17	21,50	8,79	22,70	8,79	22,15
Na_2SiO_3	Scavenger	3,80	22,02	1,22	49,51	32,94	4,22	3,90	3,55	14,44
Fuel Oil	Tailing	81,84	20,14	1,01	51,34	5,81	83,17	69,52	79,19	54,80
Burning Oil	Feed	100,00	19,82	1,19	53,07	8,67	100,00	99,97	100,00	100,00
No:4	Slime	1,63	14,88	0,65	77,22	22,00	1,64	0,48	1,54	2,83
Salt Washer	Mica	7,92	13,20	0,72	84,42	9,46	7,08	2,58	8,20	5,91
Aero 801+727	Middling	46,40	12,38	1,64	93,63	7,91	38,91	34,45	53,31	28,94
Na_2SiO_3	Concentrate	40,84	17,55	3,10	68,91	14,96	48,55	57,32	34,53	48,17
Fuel Oil	Tailing	3,23	17,46	0,37	60,84	55,56	3,82	0,54	2,42	14,15
Burning Oil	Feed	100,00	14,76	2,11	89,39	12,68	100,00	95,38	100,00	100,00
No:5	Slime	1,97	14,20	1,73	82,95	22,50	1,91	2,20	3,22	2,07
Wet Magnetic	Mica	6,78	14,07	1,62	88,30	37,17	6,50	7,09	11,81	11,77
Separation	Mag. Con.	6,49	1,71	2,02	40,50	19,34	0,76	8,46	5,19	5,86
Aero 801	Mag. Tail.	0,44	13,85	0,47	60,10	7,09	0,42	0,13	0,52	0,15
Aero 825	Non.Mag.Tail.	51,15	12,95	0,38	58,05	3,45	45,13	12,54	58,57	8,24
Na_2SiO_3	Non.Mag.Con.	14,15	19,72	4,10	43,43	43,38	19,01	37,44	12,12	28,66
Fuel Oil	Non.Mag.Midd.	19,01	20,29	2,62	22,83	48,74	26,28	32,14	8,56	43,26
Burning Oil	Feed	100,00	14,68	1,55	50,69	21,42	100,00	100,00	100,00	100,00
No:6	Slime	3,00	14,06	1,65	82,57	27,99	2,63	2,61	3,68	2,38
A 801+825	Mica	6,64	14,06	1,35	79,53	26,72	5,82	4,73	7,84	5,02
Na_2SiO_3	Concentrate	26,31	20,55	3,81	34,28	14,19	33,69	52,88	13,39	10,57
Depramin 75	Scavenger	25,46	19,82	1,78	51,18	48,19	31,44	23,90	19,34	34,73
Fuel Oil	Tailing	38,60	10,99	0,78	97,29	43,30	26,43	15,88	55,75	47,31
Burning Oil	Feed	100,00	16,05	1,90	67,36	35,33	100,00	100,00	100,00	100,00

Table 6.7 Results of flotation of Titanium Eclogite

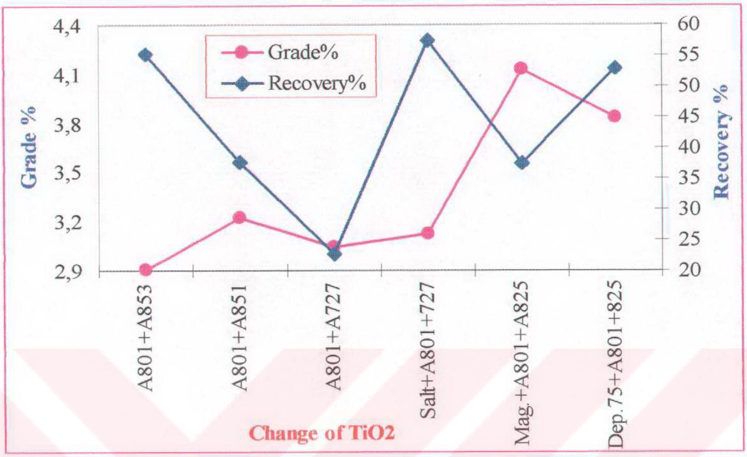

Figure 6.19 Change of grade and recovery forTiO_2 with different flotation

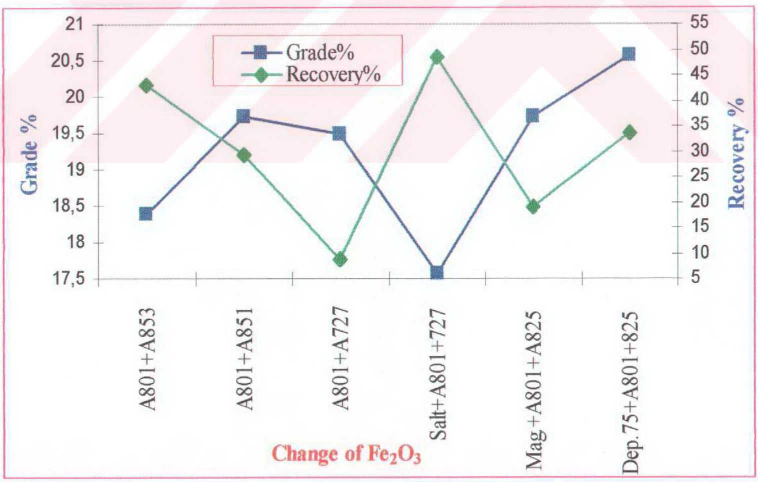

Figure 6.20 Change of grade and recovery forFe_2O_3 with different flotation.

Figure 6.21 Change of grade and recovery for SiO_2 with different flotation.

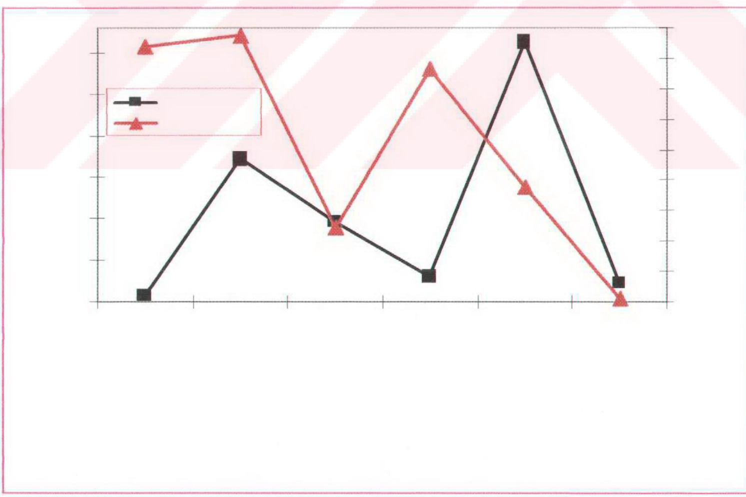

Figure 6.22 Change of grade and recovery for Al_2O_3 with different flotation.

Slime:

Dowfroth 1012 : 50 g/t.

Condition :10 min.

Mica:

pH :2.5-3 with H_2SO_4

Armac T :400 g/t.

Fuel Oil Burning Oil : 400g/t.

Dowfroth 1012 :30 g/t.

Condition :10 min.

WET MAGNETIC SEPARATOR

Nonmagnetic Product

Magnetic

Nonmagnetic Product		Magnetic	
Basic Flotation:		**Basic Flotation:**	
pH	:2.5-3 with H_2SO_4	**pH**	: 2.5-3 with H_2SO_4
Aero 801	:300 g/t	**Aero 801**	:300 g/t
Aero 825	:600 g/t	**Aero 825**	:600 g/t
Fuel Oil + Burning Oil:	300 g/t.	**Fuel Oil Burning Oil :**	300g/t
Dowfroth 1042	: 100 g/t.	**Dowfroth 1012**	: 100g/t
Condition	: 10 min.	**Conditioning**	: 10 min.

Cleaner Flotation : All the amounts of reactives feed for Cleaner used were half of basic flotation reactivces.

After all of the flotation steps, product of flotation was washed in order to pass other flotation step.

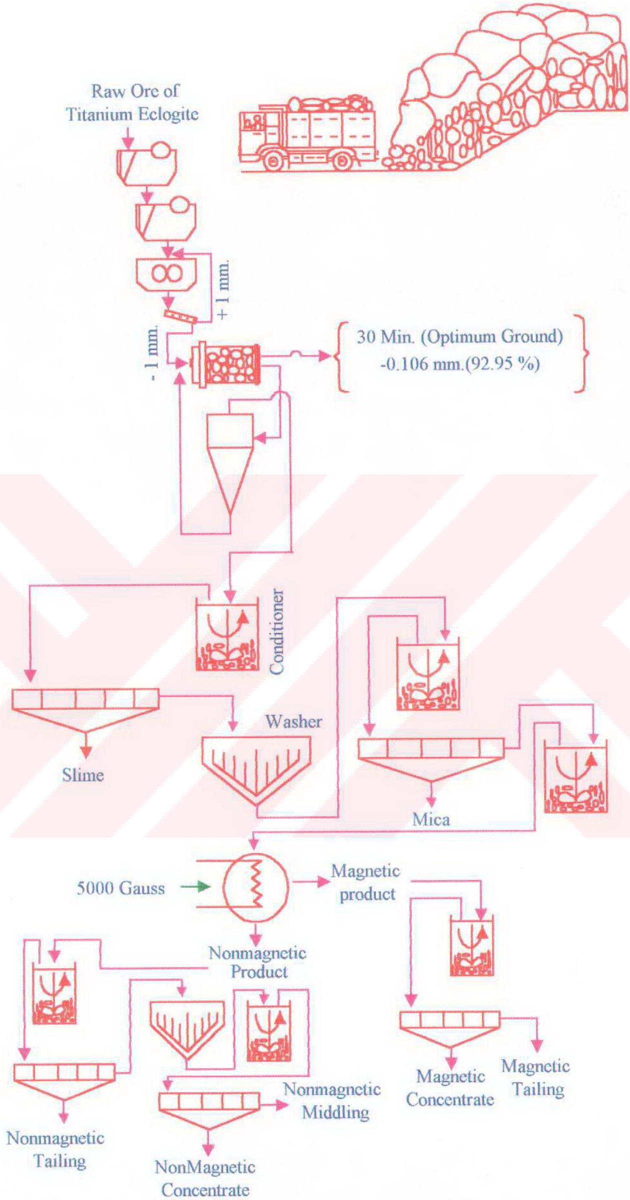

Figure 6.23 A flowsheet developed for the beneficiation of concentrate from Titanium Eclogite Ore by Flotation with Wet Magnetic Separator.

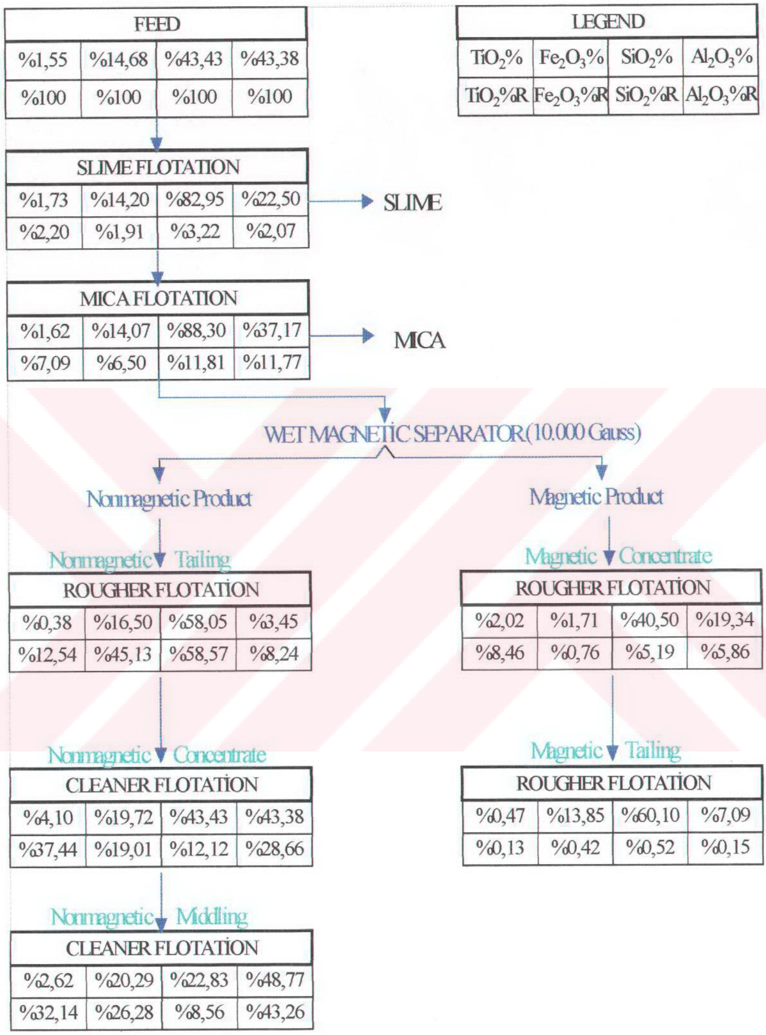

Figure 6.24. Flowsheet of concentrate recovery by Flotation with Wet Magnetic Separator

Slime:

Dowfroth 1012 : 50 g/t.

Condition :10 min.

Mica:

pH :2.5-3 with H_2SO_4

Armac T :400 g/t.

Fuel oil+ Burning Oil: 400g/t.

Dowfroth 1012 :30 g/t.

Condition :10 min.

Basic Flotation:

Ph :2.5-3 with H_2SO_4

Aero 801 :300 g/t

Aero 825 :600 g/t

Fuel Oil Burning Oil : 300g/t

Dowfroth 1012 : 100 g/t.

Depramin 75 : 200 g/t

Condition : 10 min.

Scavenger Flotation: All the amounts of reactives feed for scavenger used were half of basic flotation reactives.

After all of the flotation step, product of floatation was washer in order to pass the other flotation step.

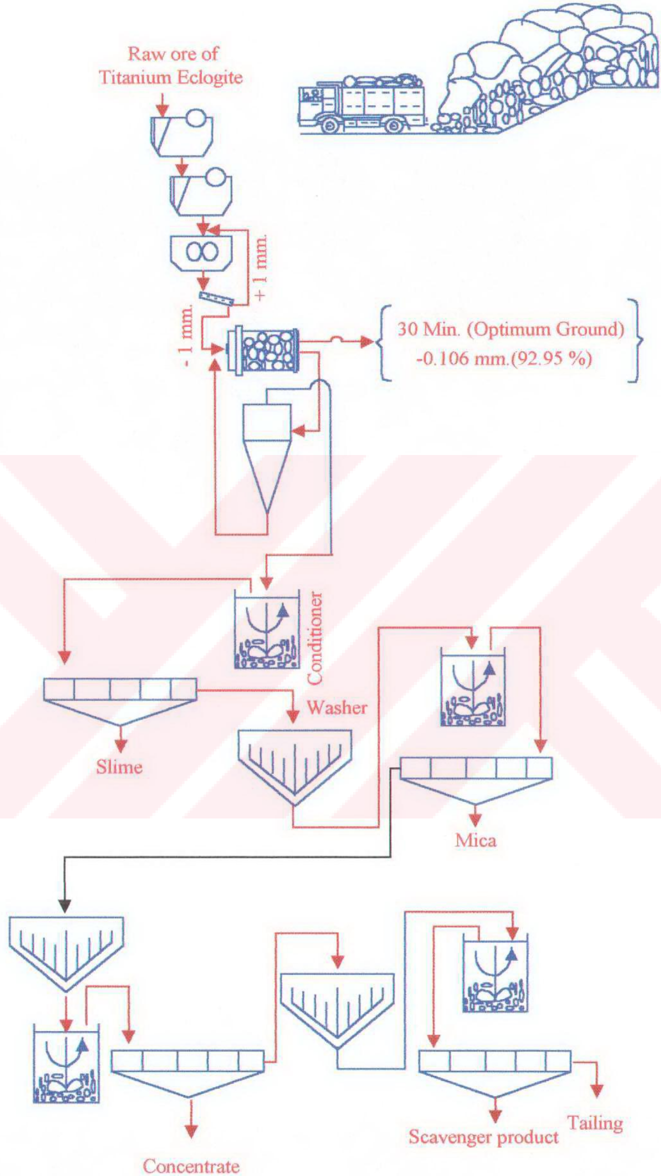

Figure 6.25. A flowsheet developed for the beneficiation of concentrate from Titanium E clogite Ore by Flotation.

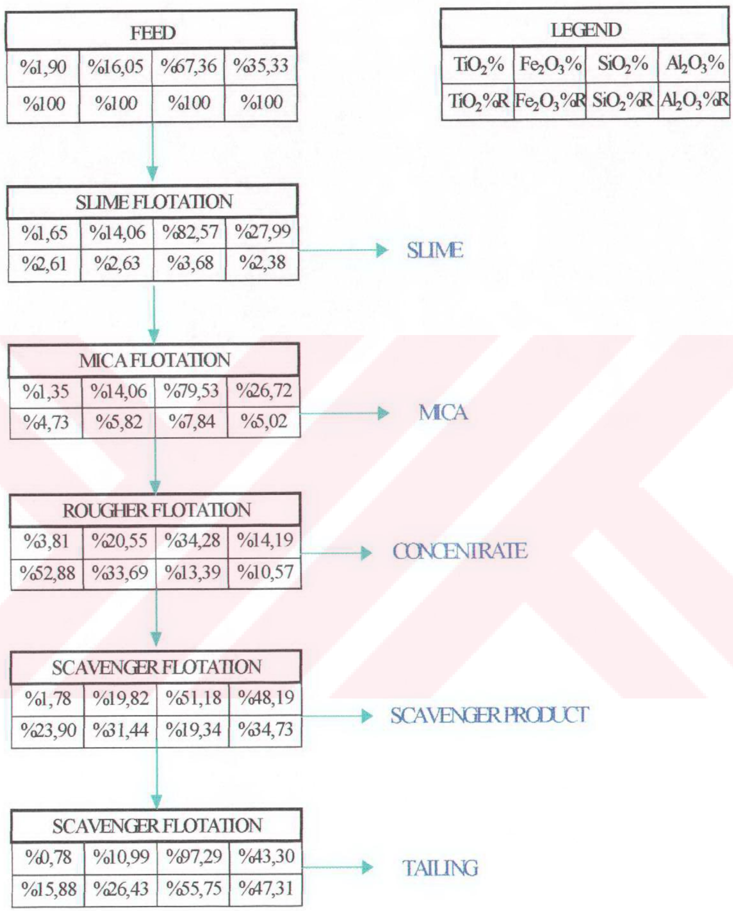

Figure 6.26 Flowsheet of concentrate recovery by flotation.

6.6 Flotation Experiments of Feldspar Ore

Flotation parameters were investigated to observe the behavior of titanium on flotation. During all the flotation tests the particle size distribution (-106 μm 96.26 %), conditioning at 50-60 % pulp density, pH 2.5-3, and impeller speed (1400 rpm) were stable and all the other parameters were variables. Moreover, the flotation experiments were carried out in a Denver type laboratory flotation machine with 2 liter cell.

Investigation of the effect of Ph change on feldspar flotation was the object of these tests. The conditions and tested are similar to Titanium Eclogite flotation.

6.6.1 Flotation Tests

Study of feldspar flotation was operated with three step. Typical practice is shown under the following operating conditions;

❖ Desliming of feldspar flotation is similar to titanium flotation.

❖ Conditioning at high pulp density with H_2SO_4 at a pH 2.5-3 with Fuel Oil + Burning Oil mixture after this, additional of frother (Armac T) and flotation of mica.

❖ Dewatering of the nonfloat from mica flotation and conditioning at high pulp density with H_2SO_4 at a pH 2.5-3 with Aero series after that, additional of Fuel Oil Burning Oil and frother. (Armac T).

In third step, Basic flotation is given heavy mineral product (TiO_2,Fe_2O_3 include) and Feldspar – Quartz product. This flotation system, Rougher feldspar concentrates are usually a satisfactory final product, but floatation cleaning may be cleaned in order to clean feldspar.The products of flotation were observed with microscope. After the microscopic examination, the best result is given in figure 6.27.

Slime:

Dowfroth 1012 : 50 g/t.

Condition :10 min.

Mica:

pH :2.5-3 with H_2SO_4

Armac T :450 g/t.

Fuel oil+ Burning Oil: 400g/t.

Dowfroth 1012 :25 g/t.

Condition :10 min.

Basic Flotation:

Ph :2.5-3 with H_2SO_4

Aero 801 :350 g/t

Aero 825 :550 g/t

Fuel Oil Burning Oil : 300g/t

Dowfroth 1012 : 100 g/t.

Depramin 75 : 200 g/t

Condition : 10 min.

Cleaner Flotation: All the amounts of reactives feed for cleaner used were half of basic flotation reactives.

After all of the flotation step, product of floatation was washer in order to pass the other flotation step.

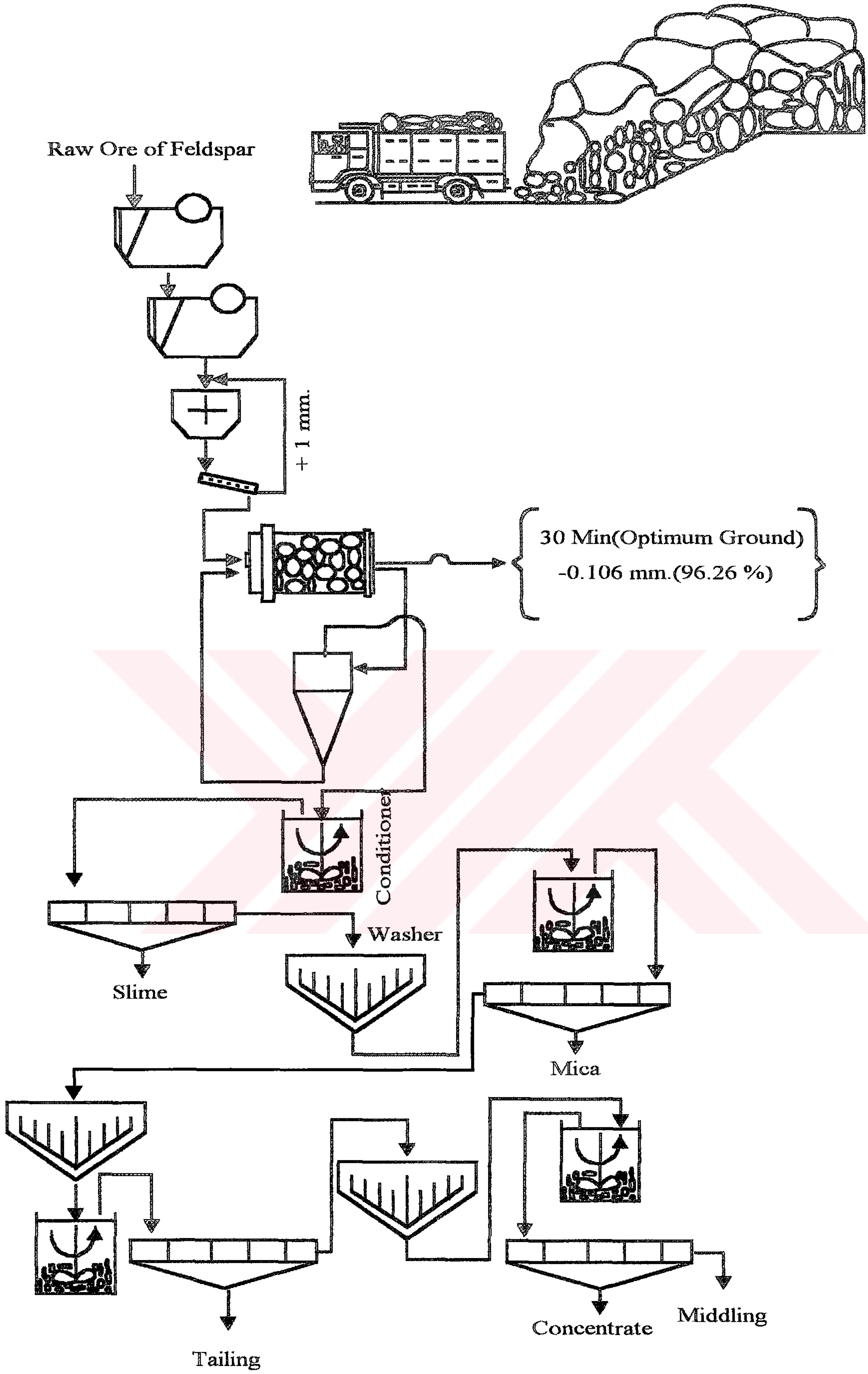

Figure 6.27 A flowsheet developed for the beneficiation of concentrate from Feldspar Ore by Flotation.

7.Conclusions

The importance of industrial raw materials has increased nowadays due to the fact that consumption of them has raised. One of them is titanium that is used widely in a large number of applications. Because of it is high refractive index, white useful for paper coatings. Another major use of titanium is aerospace. Result of its versatile properties, titanium is a "quality of life" product and are mainly consumed industrialized countries.

The most common titanium mineral (ilmenite) obtained from both rock and sand deposits. Another source is titaniferous magnetite, when both iron and titanium values can be recovered. Since natural rutile is produced only from sand deposits, that are unlikely to satisfy so a huge demand as could be anticipated if ilmenite had to be fully replaced by rutile, titanium industry is paying an increasing attention to the "alternative sources " of rutile.

Turkey has got low TiO_2 grade of titanium eclogite deposits. These are İzmir-Ödemiş, Manisa-Gördes districts etc. On the other hand, west of the Turkey has high TiO_2 grade such as Aydın-Çine district. It is expected that in the next few years, major developments will happen in the world titanium mineral industry, because pigment and sponge industry grow up. Increasing demand for pigment will forced mining sector to exploit and operate domestic titanium resources.

In this study, high titanium grade of feldspar from Aydın –Çine district and titanium eclogite deposits in Izmir- Ödemiş district were investigated. In this first step , It was determined grindibility factors. Other major experiments were carried out with MGS, Wet Tabling and Flotation in order to beneficiation of Titanium Eclogite Ore. All concentration products of titanium eclogite ore tests were passed through wet magnetic separator. In this way, iron content of the concentrate was removed. After these studies, the best results are given in Wet Tabling Tests and Flotation. The optimum conditions of wet tabling test study are presented below;

Pulp Density : 30 % Solids

Amplitude : 10-25 mm

Tilt : 1/48-1/24

Speed : 240-325 strock /min.

Enrichment tests of titanium eclogite by flotation with magnetic separator. Optimum condition of flotation was determined as follows;

Pulp Density : 25 % Solids

Particle Size : -106μm (92.95 %)

Armact T : 400 g/t

Dowfroth 1012 : 30 g/t

Fuel Oil + Burning Oil : 400 g/t

Wet Magnetic Separator : 5000 Gauss

pH : 2.5-3 with H_2SO_4

Aero 801 : 300 g./t

Aero 825 : 600 g./t

Condition : 10 min.

Cleaner Flotation : All the amounts of reactives feed for cleaner used were half of basic flotation reactives.

At feldspar tests, in order to recover titanium from feldspar ore was used only flotation method. The products of flotation were observed with microscope examination. Optimum conditions of flotation were determined as follows;

Pulp Density : 25 % Solids

Particle Size : -106μm (96.26 %)

Armact T : 450 g/t

Dowfroth 1012 : 25 g/t

Fuel Oil + Burning Oil : 400 g/t

pH : 2.5-3 with H_2SO_4

Aero 801 : 300 g./t

Aero 825 : 600 g./t

Condition : 10 min.

Cleaner Flotation : All the amounts of reactives feed for cleaner used were half of basic flotation reactives.

All of the experiments were seen that concentration was failed and, rutile could not be recovered as salable product. Incidentally, ıt was understood that only MGS concentration method will not be economical for recover rutile because of the enforcement on selling products all together. On the other hand, studies of flotation was found to be successful if only concentration technique is considered. While flotation is applicable for concentration of both two samples.

In conclusion, the highest TiO_2 grade and recovery are obtainable by means of flotation with wet magnetic separator and wet tabling. The grades reached after the combination with wet magnetic separator and flotation is 4.10 % TiO_2 with a recovery of 37.44 %. However, at wet tabling study, the grades were reached 7.46 % TiO_2 with a recovery of 98.95 %. A flowsheet of concentrator developed for titanium eclogite is presented in figure 6.15 and 6.23. Furthermore, the best result for recovery of titanium from feldspar ore is given in figure 6.27.

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