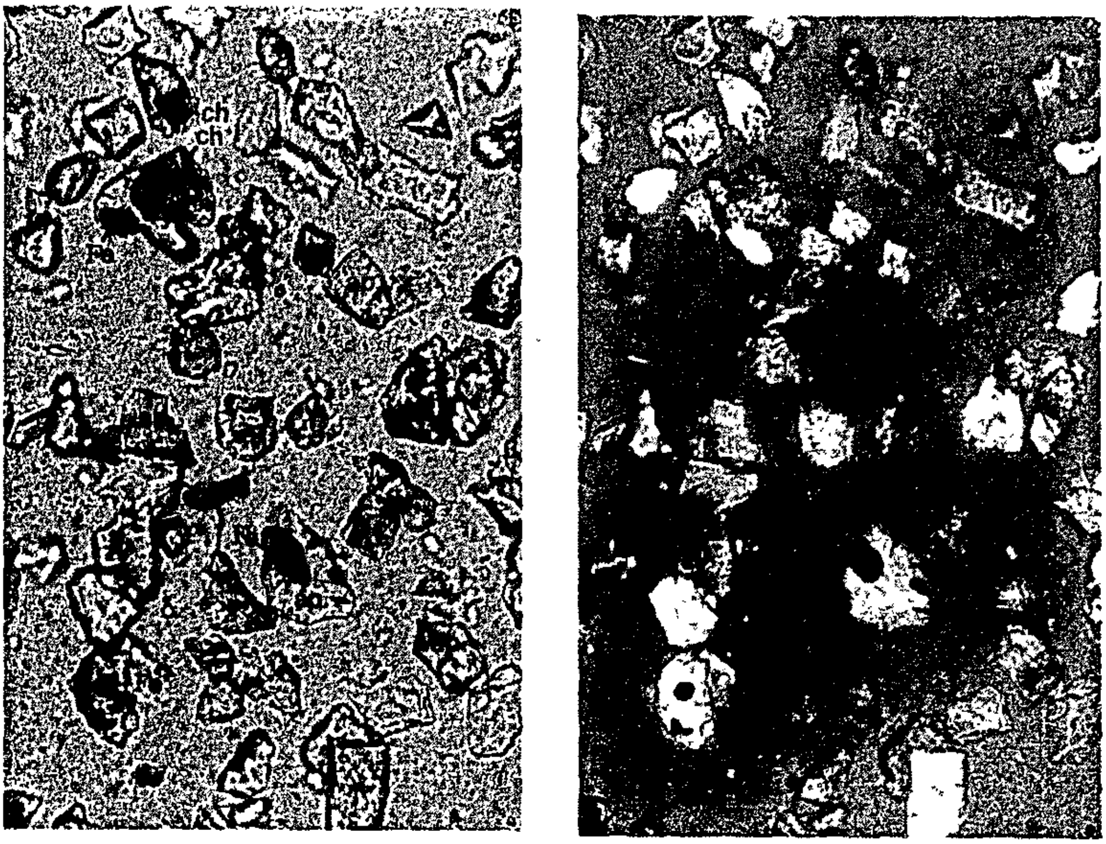
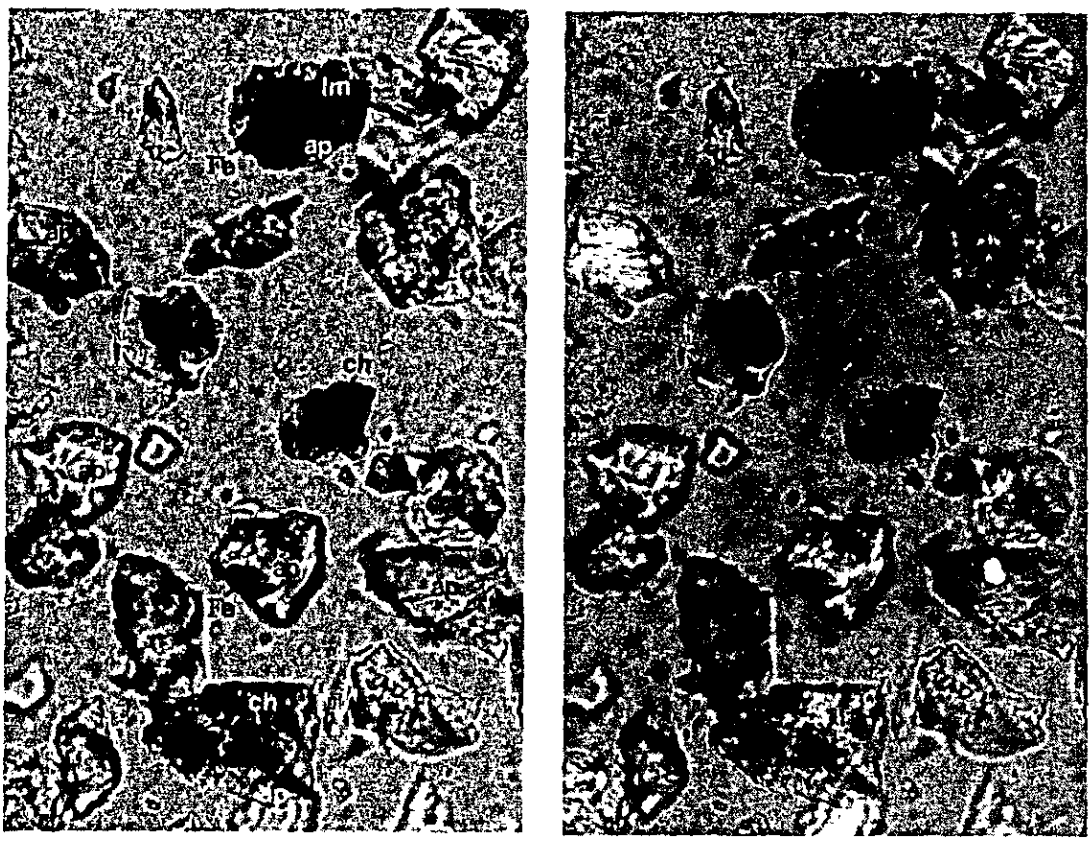
Figure AIV-1(3) Microscope Observation of Phosphate Rock, HIPASAM, Sierra Grande, Argentine

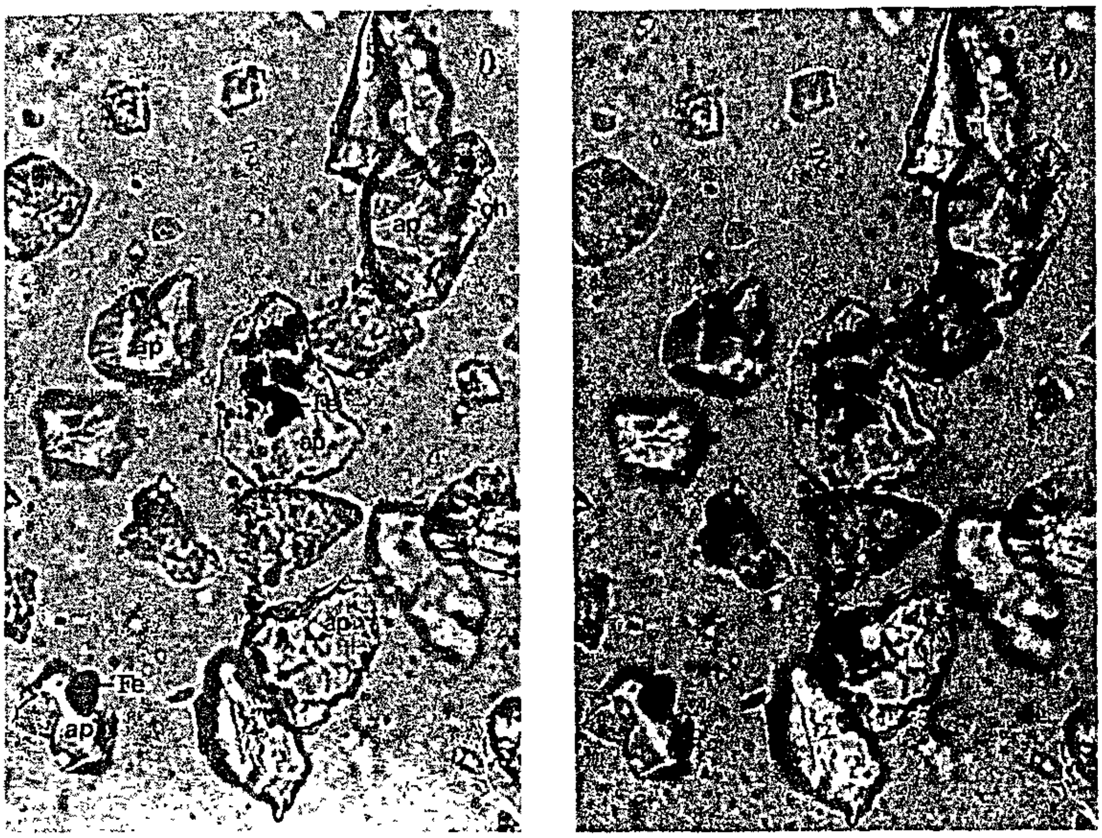


Scale: X220

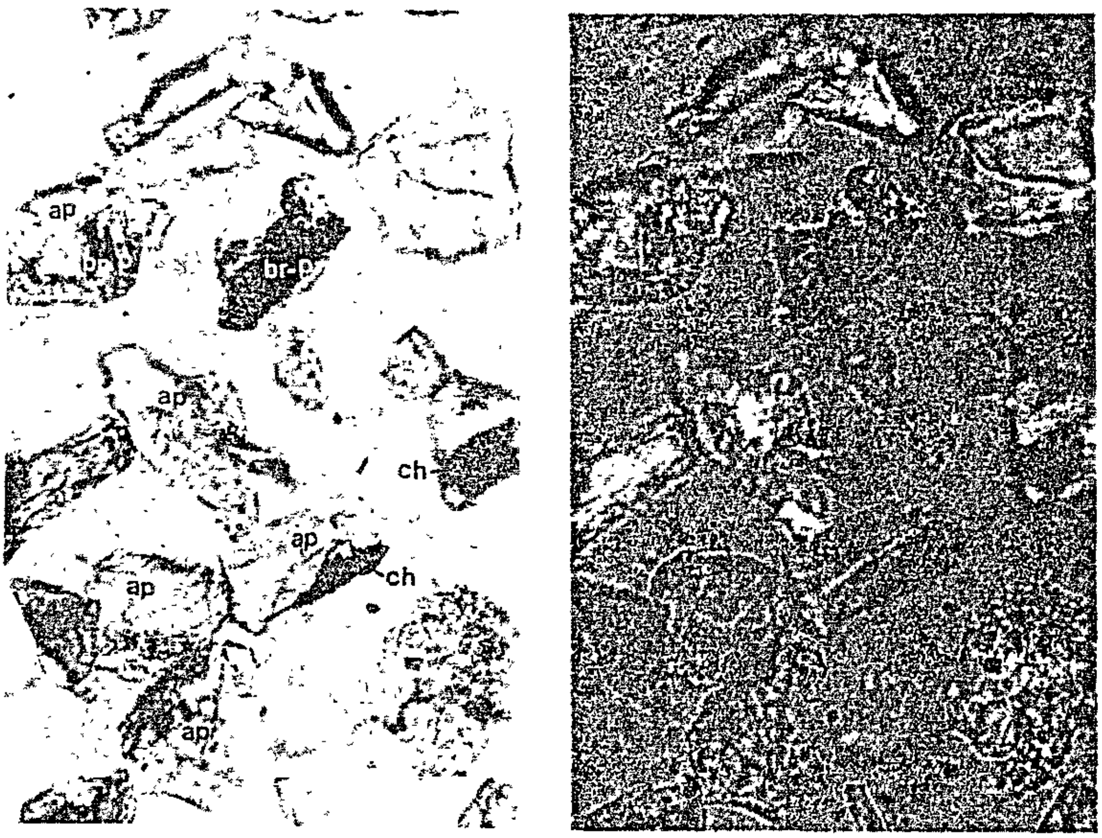


Scale: X220

Figure AIV-1(4) Microscope Observation of Phosphate Rock, HIPASAM, Sierra Grande, Argentine

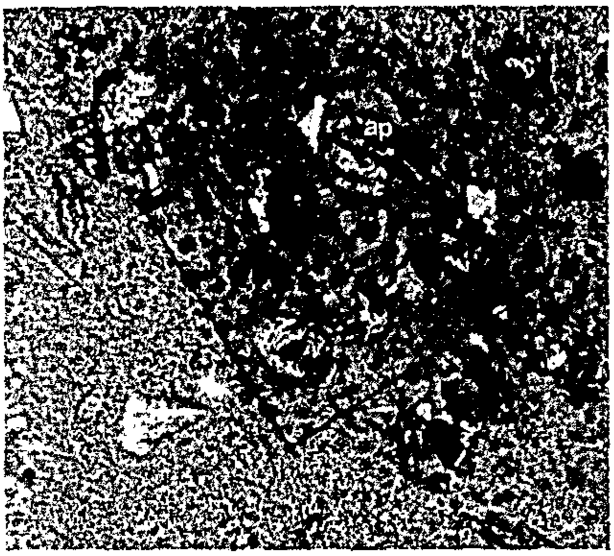


Scale: X220



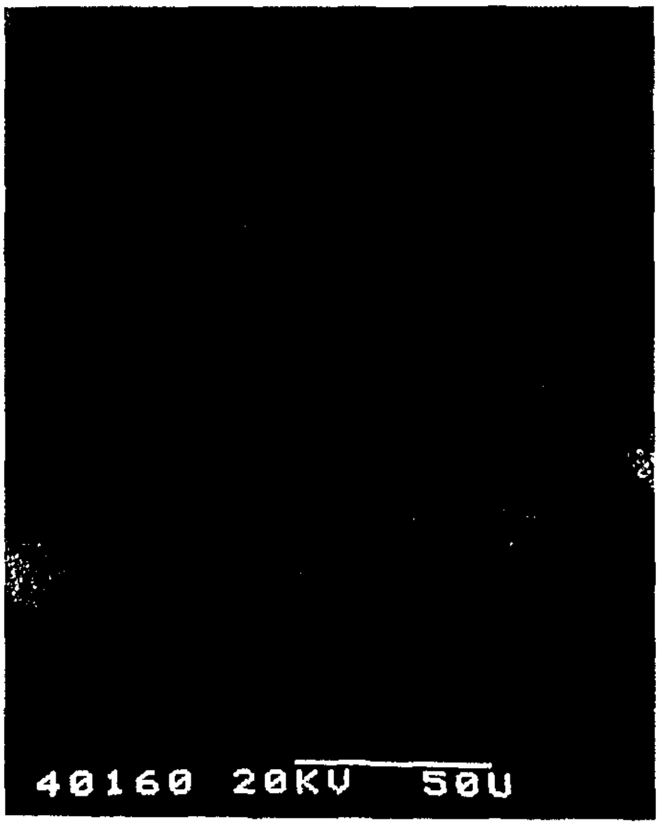
Scale: X220

Figure AIV-1(5) Electron Probe Micro Analyzer Observation of Phosphate Rock, HIPASAM, Sierra Grande, Argentine

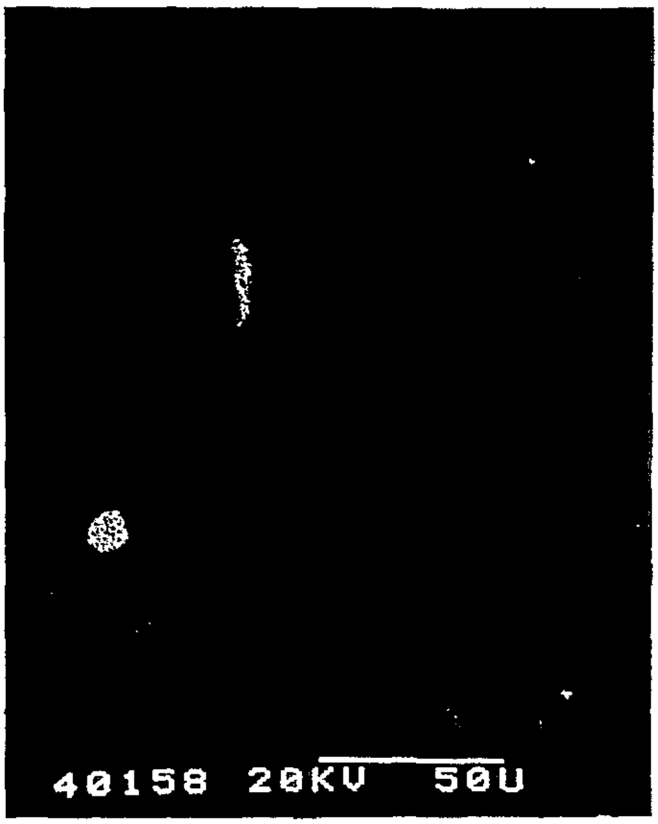


Microscope, Single Nicol
Scale: X-220

Secondary Electron Image

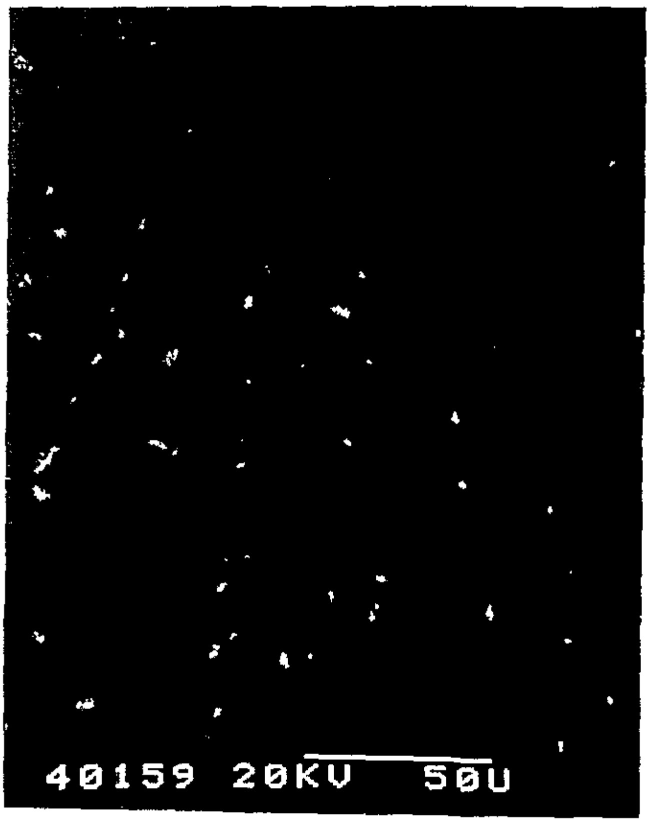


X-Ray Image, P-K alpha



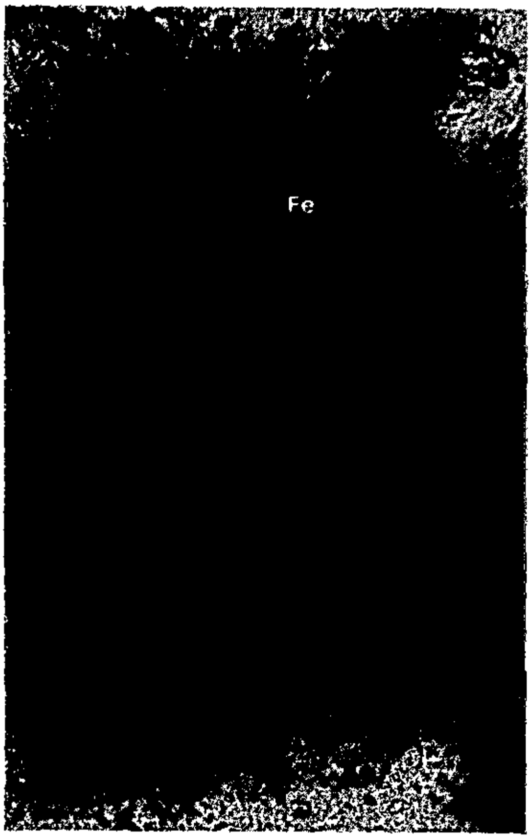
X-Ray Image, Fe-K alpha

Figure AIV-1(6) Electron Probe Micro Analyzer Observation of Phosphate Rock, HIPASAM, Sierra Grande, Argentine



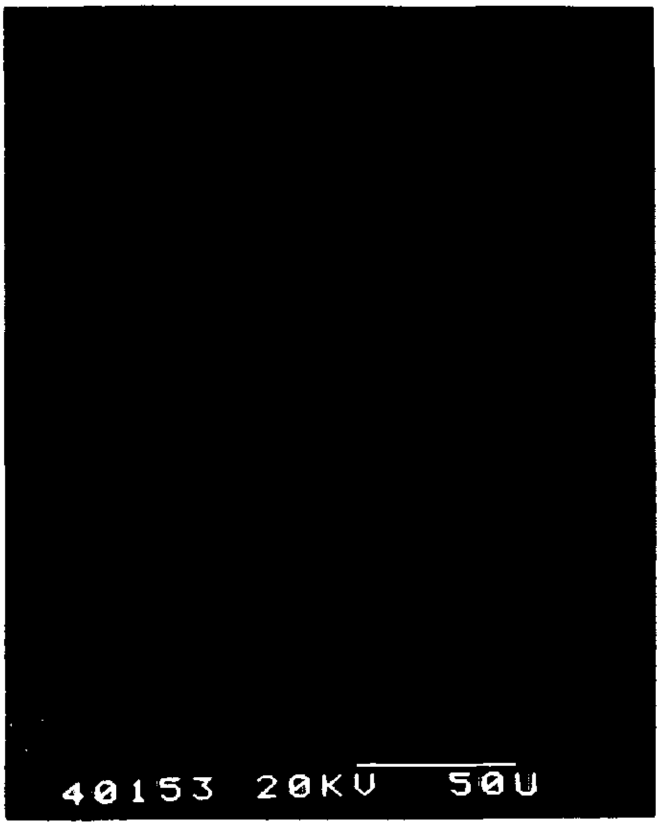
X-Ray Image, Mg-K alpha

Figure AIV-1(7) Electron Probe Micro Analyzer Observation of Phosphate Rock, HIPASAM, Sierra Grande, Argentine

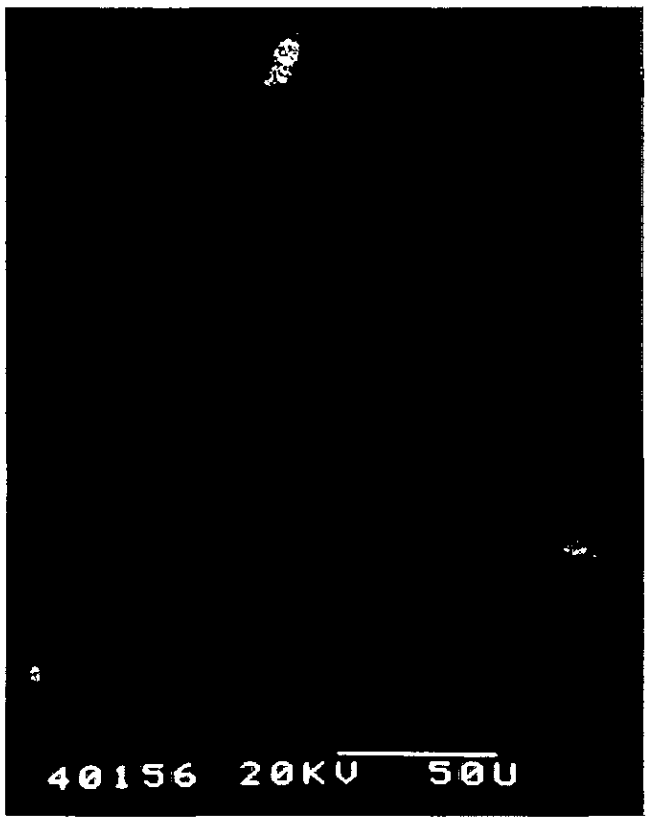


Microscope, Single Nicol
Scale: X~220

Secondary Electron Image



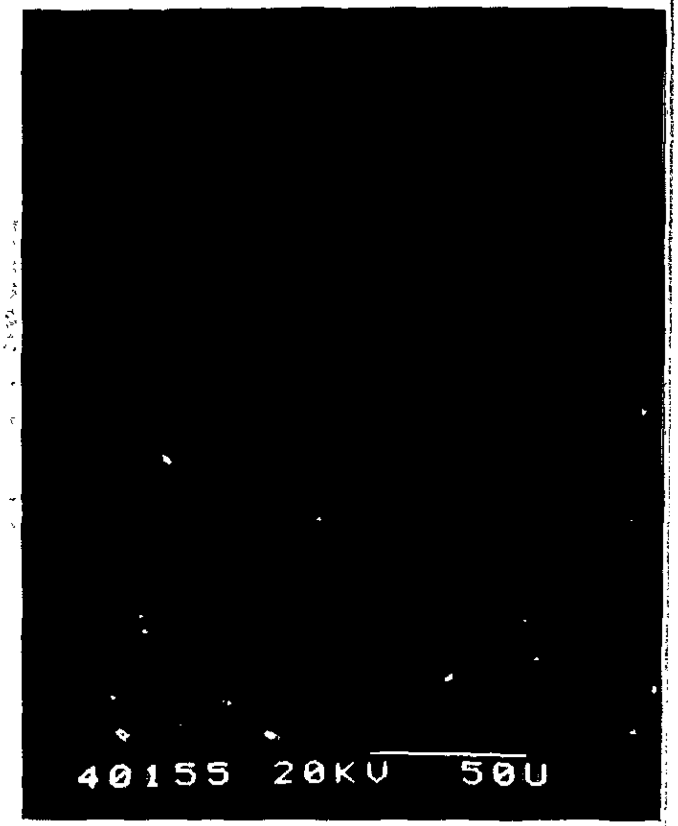
X-Ray Image, P-K alpha



X-Ray Image, Fe-K alpha

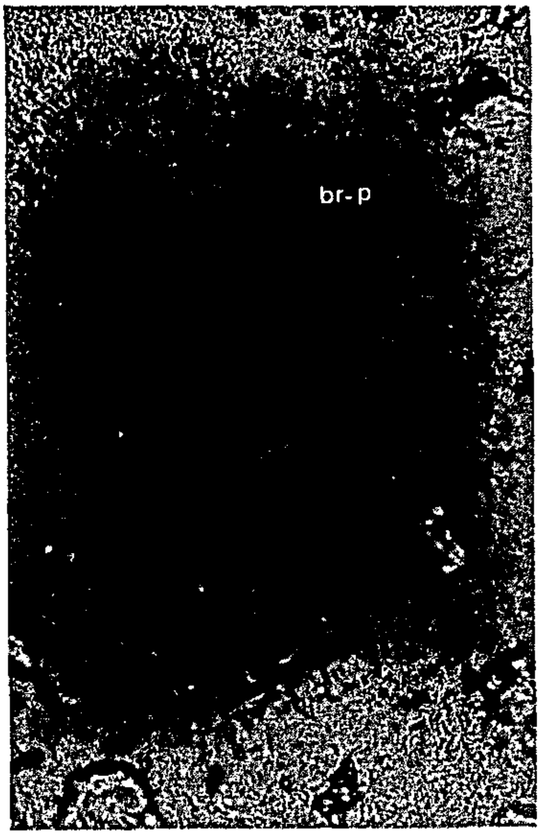
Figure AIV-1(8) Electron Probe Micro Analyzer Observation of Phosphate Rock, HIPASAM, Sierra Grande, Argentine

X-Ray Image, Ca-K alpha



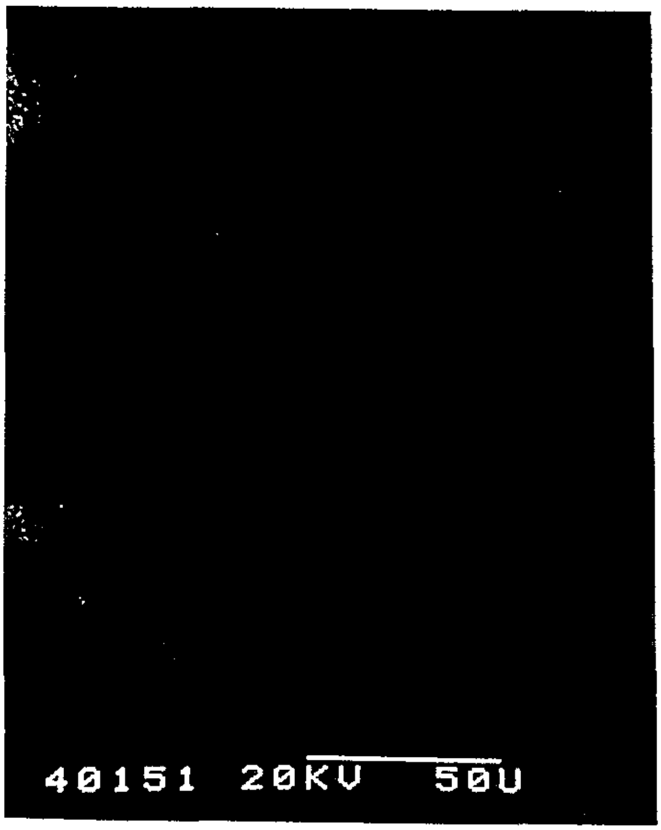
X-Ray Image, Mg-K alpha

Figure AIV-1(9) Electron Probe Micro Analyzer Observation of Phosphate Rock, HIPASAM, Sierra Grande, Argentine

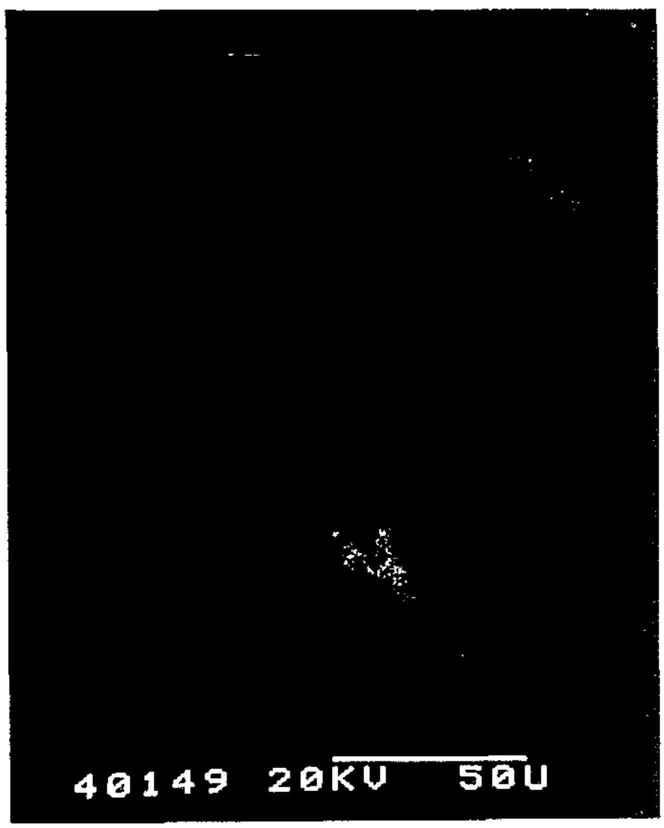


Microscope, Single Nicol
Scale: X-440

Secondary Electron Image

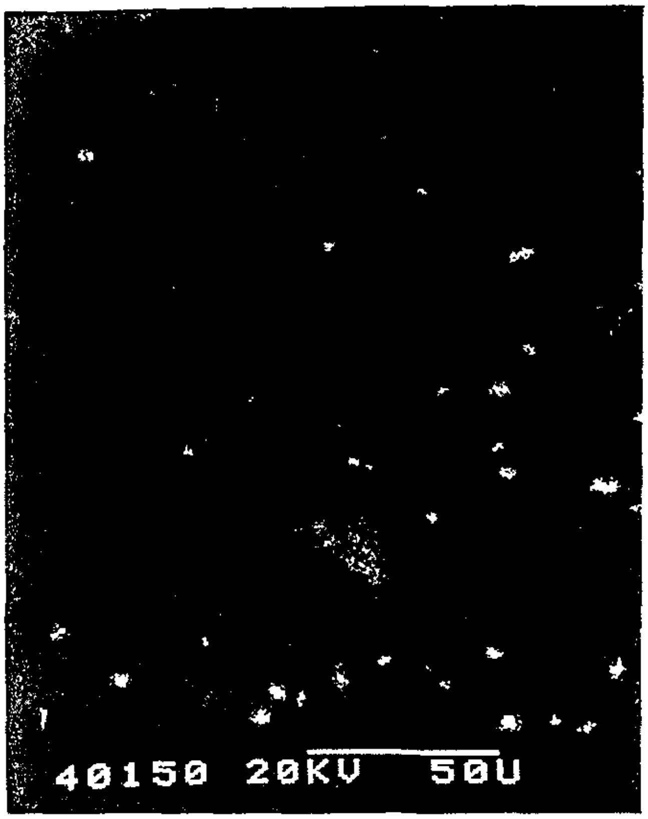


X-Ray Image, P-K alpha



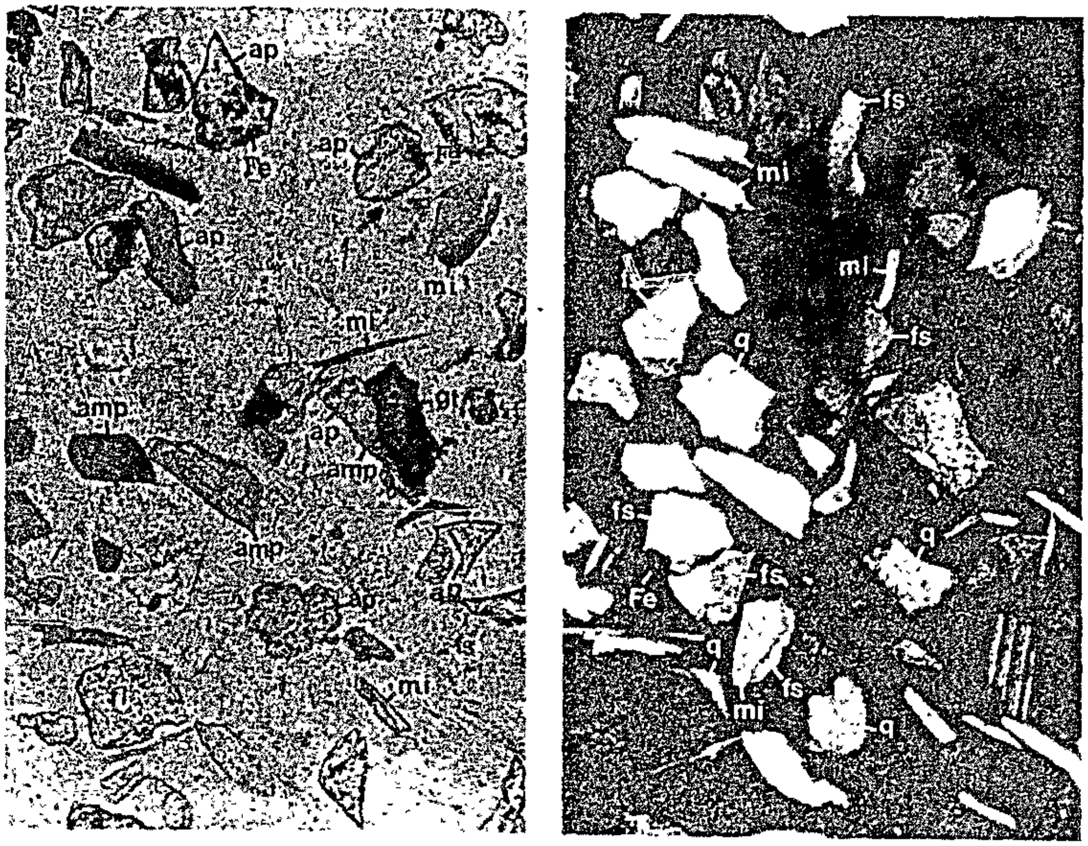
X-Ray Image, Fe-K alpha

Figure AIV-1(10) Electron Probe Micro Analyzer Observation of Phosphate Rock, HIPASAM, Sierra Grande, Argentine

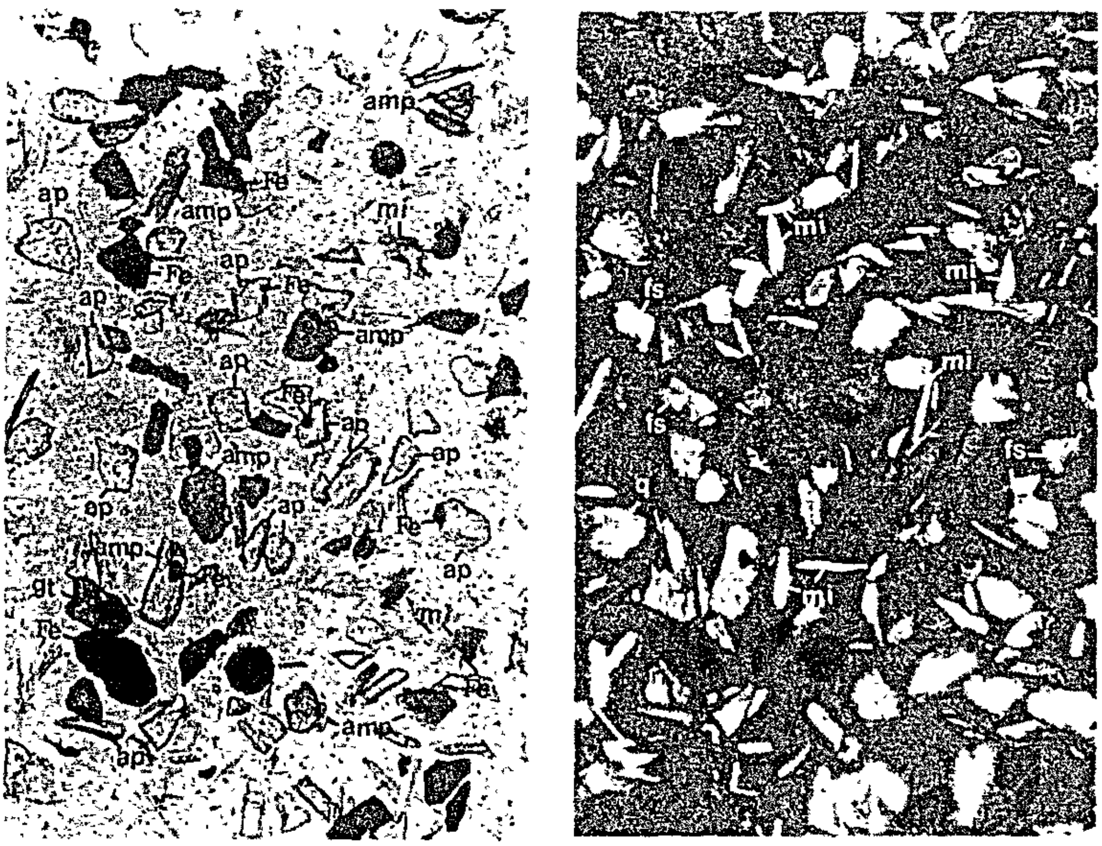


X-Ray Image, Mg-K alpha

Figure AIV-1 (11) Eletron Probe Micro Analyzer Observation of Phosphate Rock, SSAB, Grängesberg, Sweden

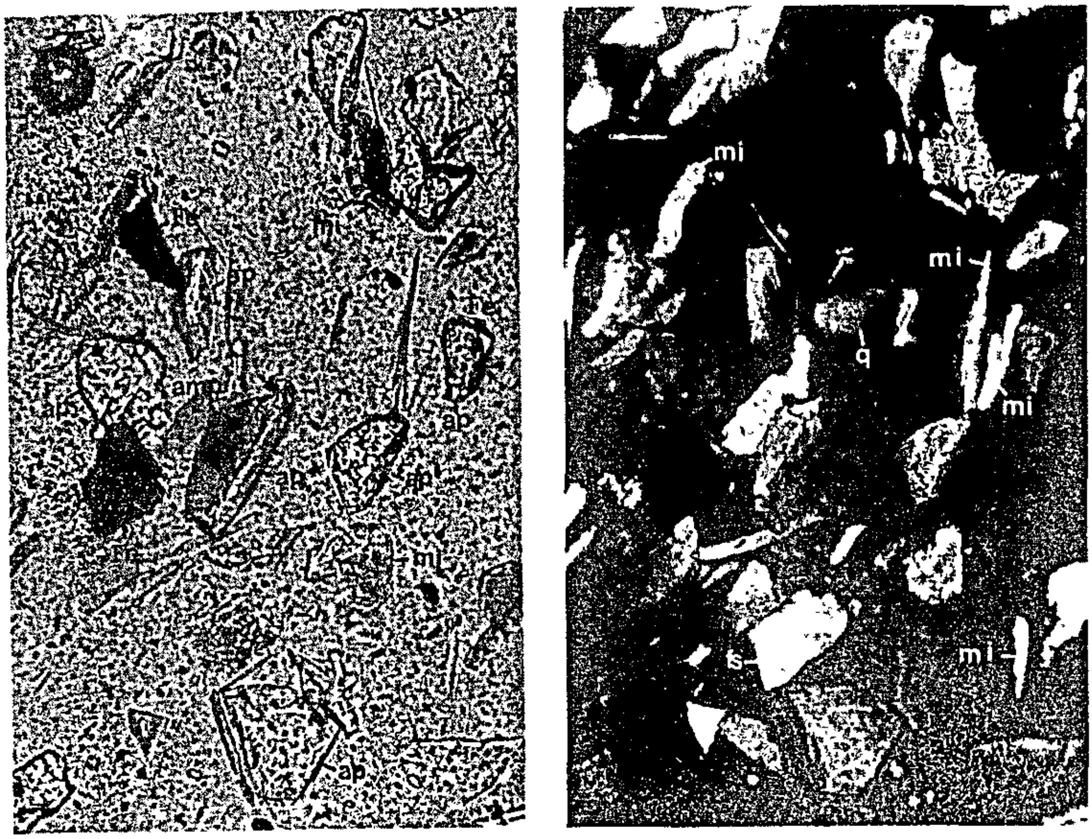


Scale: X-110

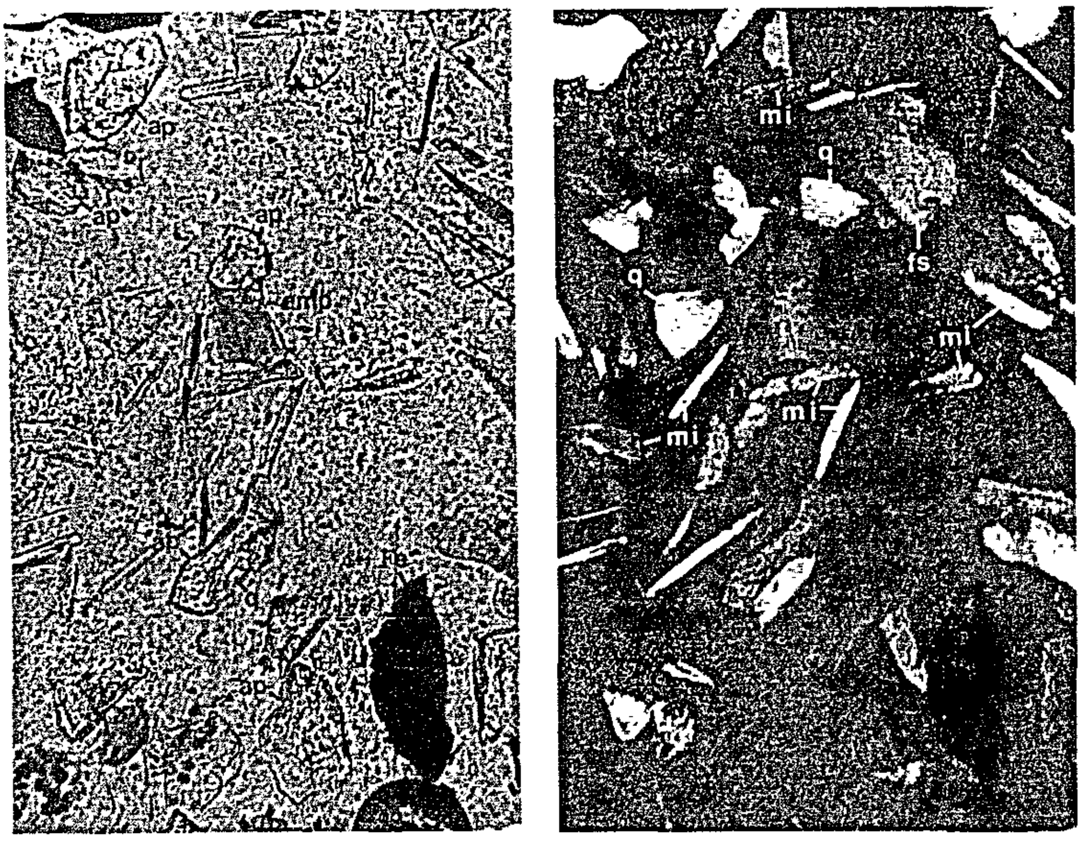


Scale: X-110

Figure AIV-1(12) Microscope Observation of Phosphate Rock, SSAB, Grängesberg, Sweden

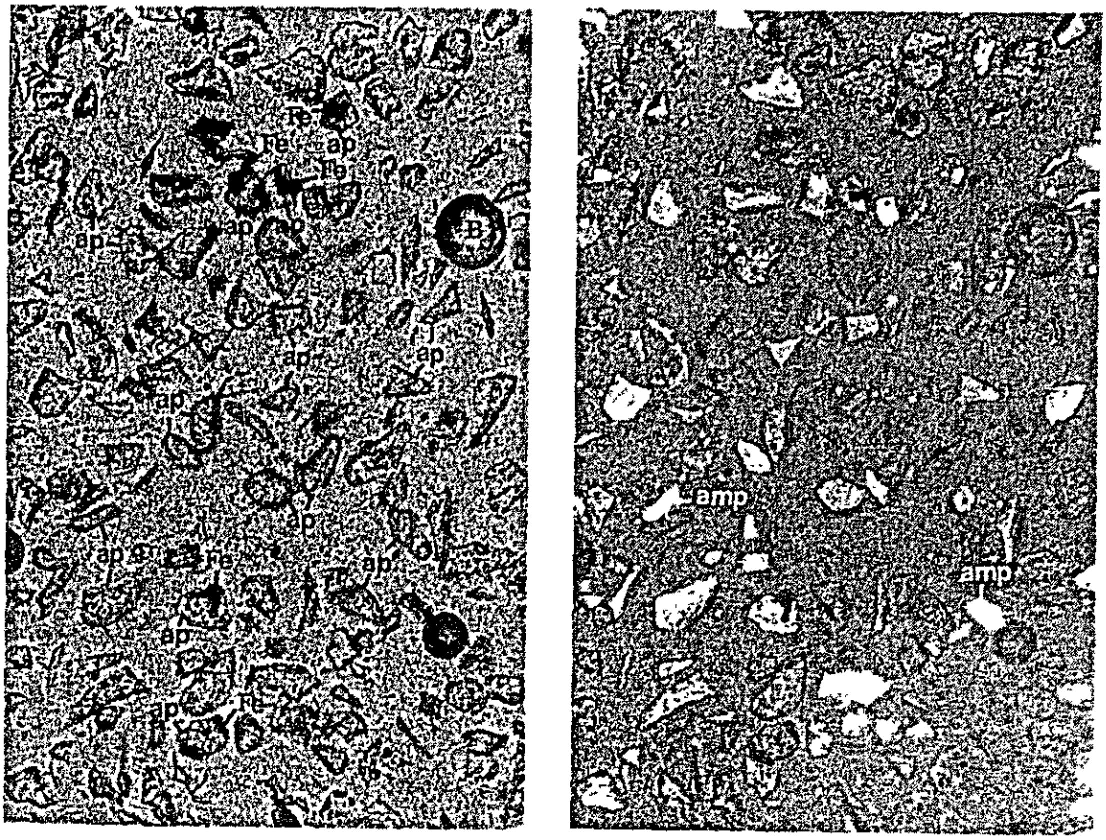


Scale: X220

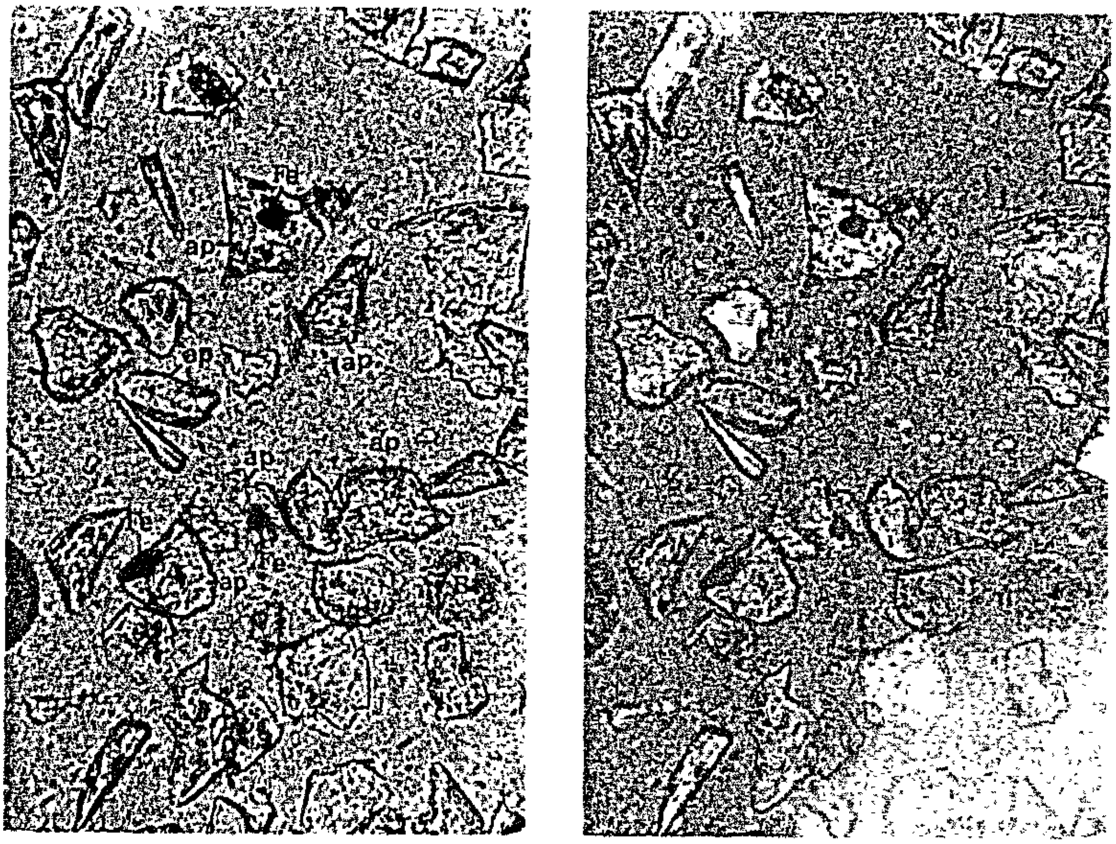


Scale: X220

Figure AIV-1(13) Microscope Observation of Phosphate Rock, SSAB, Grängesberg, Sweden

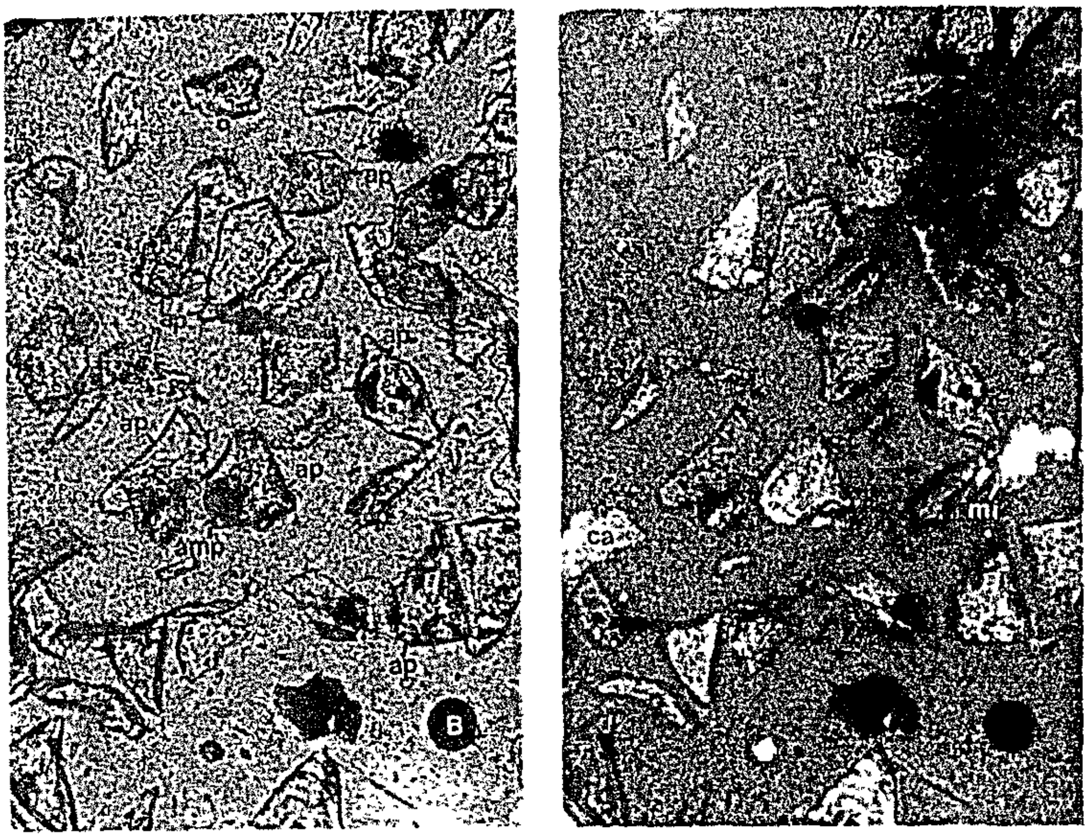


Scale: X110

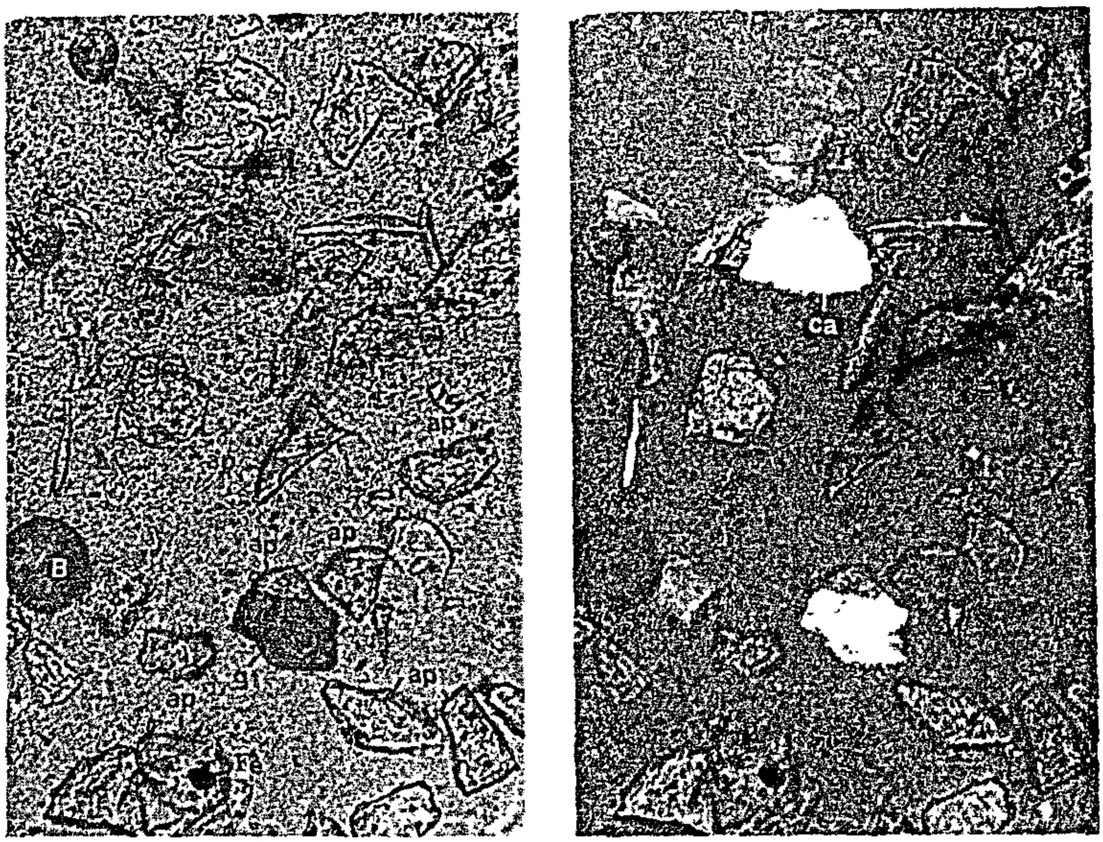


Scale: X220

Figure AIV-1(14) Microscope Observation of Phosphate Rock, SSAB, Grängesberg, Sweden



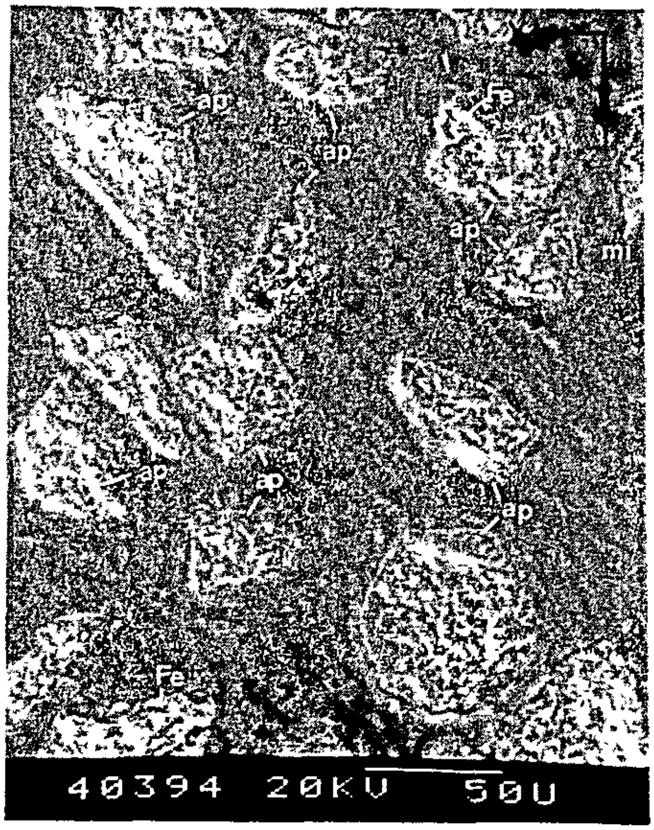
Scale: X220



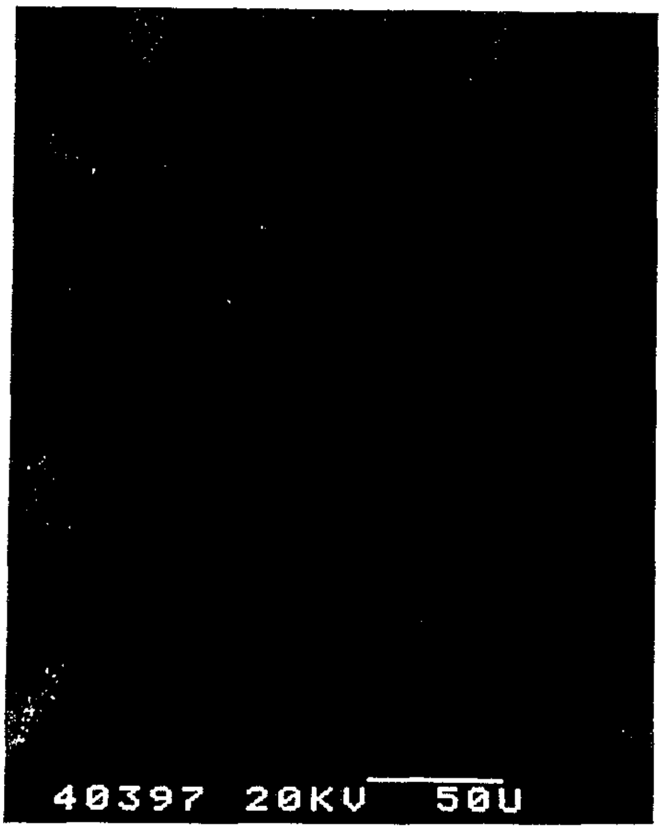
Scale: X220

Figure AIV-1 (15) Eletron Probe Micro Analyzer Observation of Phosphate Rock, SSAB, Grängesberg, Sweden

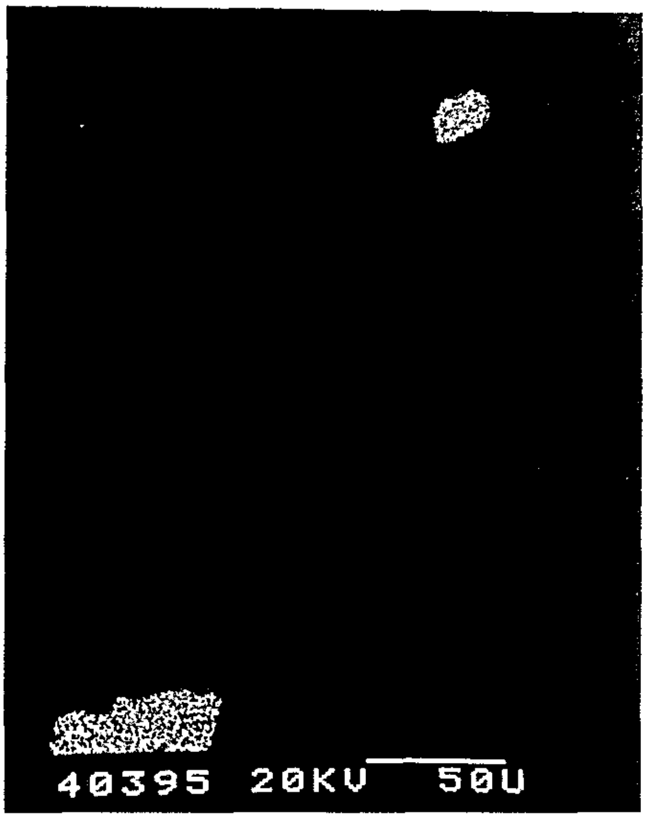
Microscope, Single Nicol
Scale: X-220



Secondary Electron Image

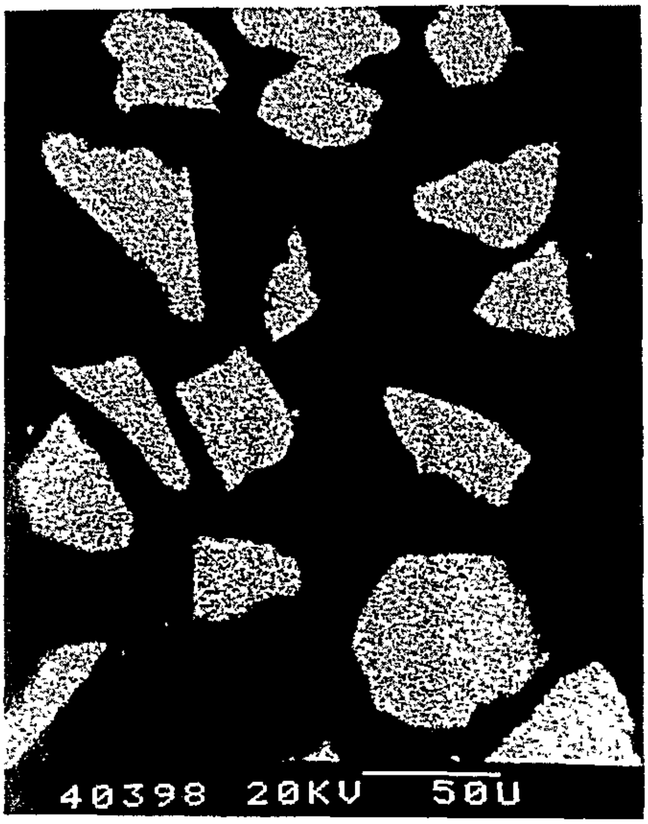


X-Ray Image, P-K alpha

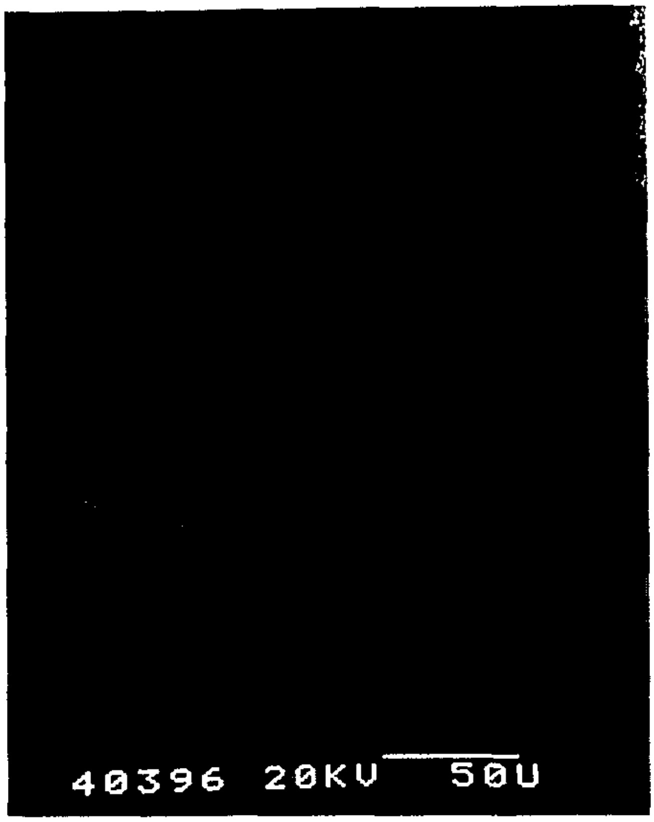


X-Ray Image, Fe-K alpha

Figure AIV-1 (16) Eletron Probe Micro Analyzer Observation of Phosphate Rock, SSAB, Grängesberg, Sweden

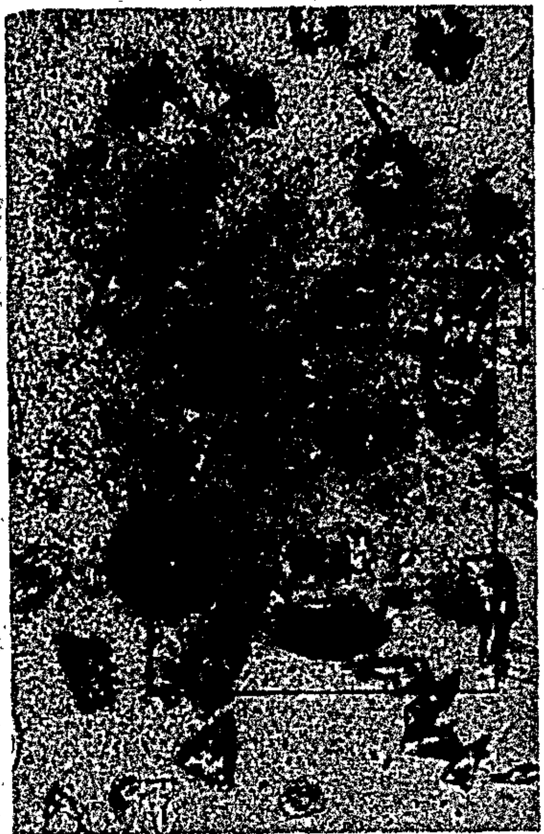


X-Ray Image, Ca-K alpha



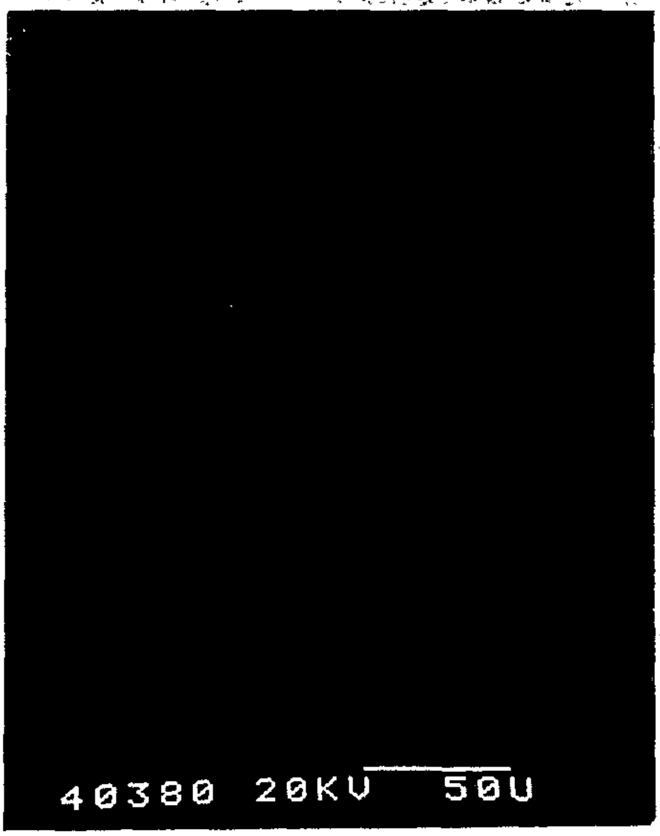
X-Ray Image, Mg-K alpha

Figure AIV-1 (17) Eletron Probe Micro Analyzer Observation of Phosphate Rock, SSAB, Grängesberg, Sweden

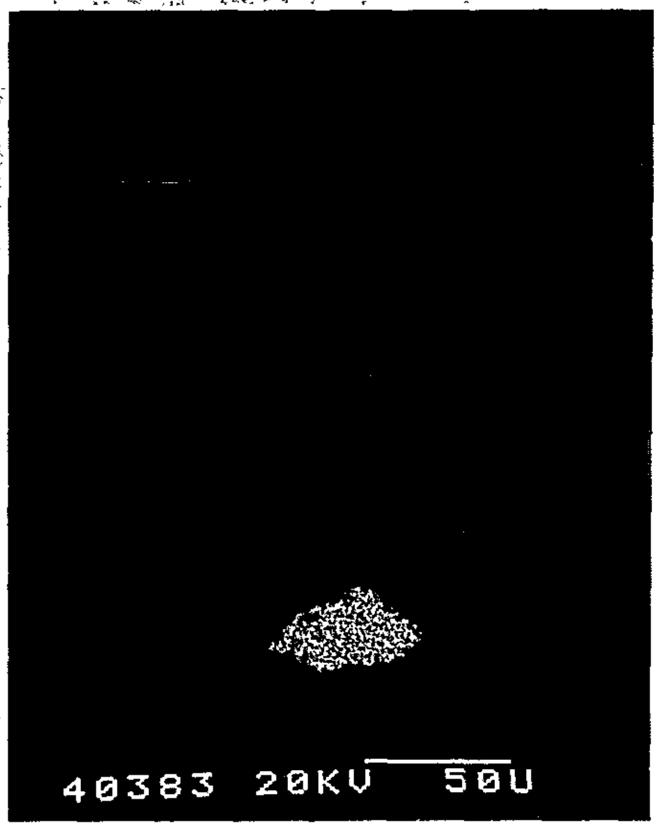


Microscope, Single Nicol
Scale: X-220

Secondary Electron Image



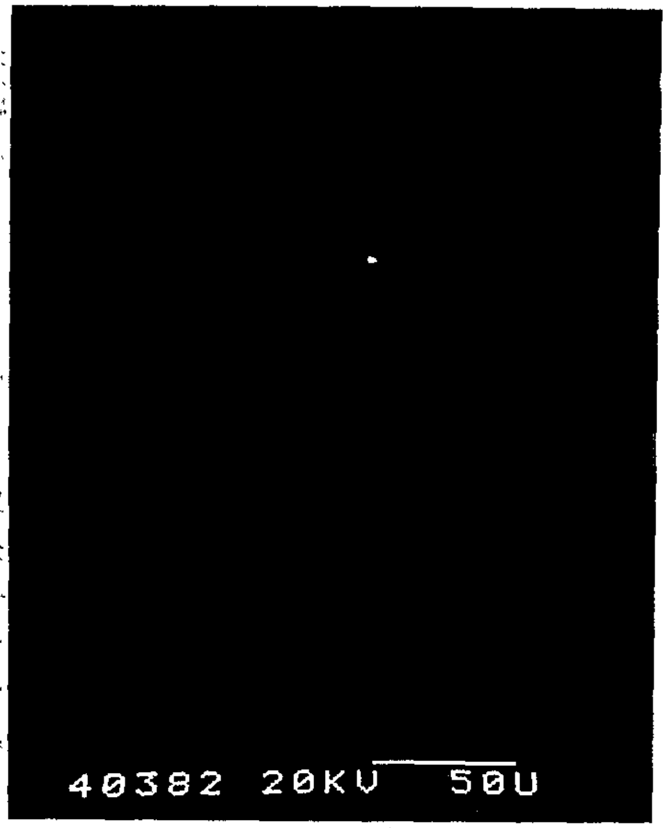
X-Ray Image, P-K alpha



X-Ray Image, Fe-K alpha

Figure AIV-1 (18) Eletron Probe Micro Analyzer Observation of Phosphate Rock, SSAB, Grängesberg, Sweden

X-Ray Image, Ca-K alpha



X-Ray Image, Mg-K alpha

(2) Non-Magnetic Tails of Grängesberg

The minerals identified in the non-magnetic tails of Grängesberg by the microscopic observation are;

Major Minerals	: Mica (Biotite and Phlogopite), Amphibole, Feldspar (Plagioclase)
Associated Minerals	: Iron Minerals (Magnetite and Hematite), Quartz, Garnet, Fluorite, Calcite

Slightly less than a half of apatite is locked with iron minerals and to some extent with mica, amphibole and quartz in a variety of locking type of simple locking to complex locking, and a little more than a half of apatite is liberated. In the case of iron minerals locking with apatite, the inclusion of small grains of iron minerals with 0.01 to 0.03mm diameter in apatite crystals are also observed.

(3) Phosphate Rock from Sierra Grande

The minerals identified are;

Major Minerals	: Apatite
Associated Minerals	: Chlorite, Quartz, Feldspar, Iron Minerals, Phosphate Minerals (Blue Colored and Brown Colored)

The majority of apatite crystals are liberated, but locked apatite with iron minerals and chlorite are also identified. Inclusion type locking of iron minerals in apatite crystals are observed widely. The phosphate minerals with blue and brown colored are also locked with apatite.

(4) Phosphate Rock from Grängesberg

The minerals identified by microscopic observation are;

Major Minerals : Apatite

Associated Minerals : Amphibole, Calcite, Quartz, Fluorite, Mica, Iron Minerals

The majority of apatite crystals are liberated, but locked apatite with iron ore, as are observed in the non-magnetic tails, are identified. The locking with amphibole and calcite are observed, too.

2-4 X-Ray Diffraction

The X-ray diffraction analysis were made to identify the minerals in the four samples and also to investigate the type of apatite minerals and chlorite minerals in the extracted phosphate rock for Sierra Grande and Grängesberg.

(1) Major Materials

The minerals identified by the X-ray diffraction are summarized as follows:

	HIPASAM Sierra Grande, Argentine		SSAB Grängesberg, Sweden	
Identified Minerals by X-ray Diffraction	Non-Magnetic Tails	Phosphate Rock	Non-Magnetic Tails	Phosphate Rock
- Fluorapatite	CC	A	B	AA
- Hydroxyapatite	CC	A	-	-
- Magnetite	CC	-	-	-
- Hematite	C	-	-	-
- Chlorite	AA	CC	-	-
- Quartz	CC	-	CC	-
- Feldspar	-	-	B	-
- Amphibole	-	-	B	-
- Mica	CC	-	A	-
- Calcite	-	-	C	C

Notes: Intensity of X-ray diffraction is measured in following degree of strength: AA > A > BB > B > CC > C > and (-) which indicated "not identified".

(2) Apatite

The X-ray diffraction of phosphate rock extracted from the non-magnetic tails of Sierra Grande and Grangesberg where analyzed to identify the type of apatite minerals.

The relative intensity of X-ray diffraction and corresponding distance of crystal lattice in Angstrom (d, A) for the phosphate rock samples and standards data for hydroxyapatite, fluorapatite, carbonate apatite and chloroapatite are shown in Table AIV-3.

The identification of the type of apatite in the extracted phosphate rock samples by X-ray diffraction is not so clear because the diffraction patterns of fluorapatite and hydroxyapatite are very similar. However, it is estimated that apatite in Sierra Grande is a mixture of hydroxyapatite and fluorapatite, and apatite in Grangesberg is mostly fluorapatite.

The low speed scanning at 2.7 Angstrom region reveals that two peaks of 2.71 and 2.73 Angstrom of Sierra Grande sample indicate that the mixture of hydroxyapatite and fluorapatite. Generally the diffraction peak of Sierra Grande sample is appeared at a little lower with 0.01 to 0.03 Argstrom than those of Granbesberg.

It is also estimatd that the both phosphate rock contain no chloroapatite nor carbonateapatite.

The above estimations are also verified by the chemical analysis as in shown in Table AIV-1.

Table AIV-3 X-Ray DIFFRACTION DATA OF PHOSPHATE ROCK EXTRACTED FROM NON-MAGNETIC TAILS

Phosphate Rock				Apatites							
HIPASAM Sierra Grande, Argentine		SSAB Grangesberg, Sweden		Hydroxy apatite $3Ca_3(PO4)_2CaF_2$		Fluor apatite $3Ca_3(PO4)_2Ca(OH)_2$		Carbonate apatite $3Ca_3(PO4, CO_3)_2Ca(OH)_2$		Cnlor apatite $3Ca_3(PO4)_2 \cdot CaCl_2$	
d	I	d	I	d	I	d	I	d	I	d	I
8.26	9	8.11	6	8.17	2	8.12	8	8.28	30	8.34	5
5.27	2	5.24	3	5.26	6	5.25	4	5.294	20	5.28	5
4.72	2	4.69	<1	4.72	4	4.72	<1	4.734	20	-	-
4.09	7	4.06	6	4.07	10	4.055	8	4.082	20	-	-
3.90	6	3.88	5	3.88	10	3.872	8	3.909	20	-	-
3.54	9	-	-	3.51	2	3.494	<1	-	-	3.54	5
3.45	61	3.44	60	3.44	40	3.442	40	3.451	70	3.39	40
3.18	11	3.17	16	3.17	12	3.167	14	3.162	20	3.15	15
-	-	-	-	-	-	-	-	3.092	50	-	-
3.09	18	3.07	18	3.08	18	3.067	18	-	-	-	-
-	-	-	-	-	-	-	-	2.822	100	2.853	100
2.83	100	2.81	100	2.814	100	2.800	100	-	-	-	-
2.79	56	2.77	42	2.778	60	2.772	55	-	-	2.770	100
2.73	61	2.71	52	2.720	60	2.702	60	2.722	90	-	-
2.71	30	-	-	-	-	-	-	-	-	-	-
2.63	25	2.63	18	2.631	25	2.624	30	2.636	40	2.628	5
2.54	. 4	2.52	8	2.528	6	2.517	6	2.531	10	-	-
-	-	-	-	-	-	-	-	2.448	5	-	-
2.30	8	2.29	6	2.296	8	2.289	8	-	-	2.306	40
-	-	-	-	-	-	-	-	2.271	70	-	-
2.27	14	2.26	28	2.262	20	2.250	20	-	-	-	-
-		-		ASTM-9-432		ASTM-15-876		ASTM-15-100		ASTM-24-214	

Notes: d=(Å), I=Intensity

(3) Chlorite

Chlorite is an alumino-silicate minerals and contains various elements such as Mg, Al, Mg, Fe(III) and Fe(II) according to the origin. It was found that chlorite is an associated minerals in non-magnetic tails of HIPASAM, Sierra Grande, Argentine and also found in the extracted phosphate rock which is a reason for high residual iron content in the phosphate rock.

The X-ray diffraction of chlorite shows distinct peaks at 4.7(003), 7.0(002) and 14.0(001) Angstrom and its relative intensity is correlated with metal element such as Mg, Al and Fe in chlorite.

It was found that chlorite in the phosphate rock extracted from the non-magnetic tails of Sierra Grande has similar X-ray diffraction peak intensity to those of chamosite [(Fe 1.7 Mg 0.2 Al 0.8)(Si 1.2 Al 0.2)$O_5(OH)_4$] or Cronstedtite [$Fe(II)_2$ $F(III)_2$ $SiO_5(OH)_4$] and quite different from Clinochlore [$Mg_5Al(Si_3Al)O_{10}$ $(OH)_8$] all of them belong to chlorite minerals. Judging from the correlation, the chlorite in the phosphate rock from Sierra Grande is considered to have high iron and low magnesium element in the mineral.

2-5 X-Ray Micro-Analyzer

The X-ray micro-analyzer investigation were made of phosphate rock extracted from the non-magnetic tails from Sierra Grande and Grangesberg to check the element distribution in the apatite crystals. The photograph of X-ray micro-analyzer is shown in Figure AIV-1.

(1) Phosphate Rock from Sierra Grande

From apatite crystal, strong X-ray of P(K-alpha), Ca(K-alpha) and a weak X-ray of Fe(K-alpha) are observed. There are some area in crystal of high X-ray of Fe but generally the X-ray of Fe seems distributed evenly in the all surface of apatite crystals.

From iron minerals only X-ray of Fe(K-alpha) is detected and no X-rays were detected for P, Ca and Mg.

From chlorite crystal, strong X-ray of Fe and Mg are observed but no X-ray was observed for P in the chlorite.

From phosphate minerals (bule colored), the X-ray of Ca, P, Fe and Mg were identified and from phosphate minerals (brown colored), the X-ray of P, Fe and Mg were detected.

(2) Phosphate Rock from Grängesberg

From apatite crystal, strong X-ray of P(K-alpha) and P(K-alpha) but no X-ray of Fe was observed.

From iron minerals only X-ray of Fe(K-alpha) was identified and no X-ray were detected for P, Ca and Mg.

From mica crystals, strong X-ray of Mg(K-alpha) is detected and no X-ray were detected for P, Ca and Mg.

Therefore, judging from the X-ray micro-analyzer observation the mica mineral in the phosphate rock from Grängesberg is considered to be biotites with close to phlogopite minerals.

2-6 Mineralogical Observation of Iron in Phosphate Rock from Sierra Grande

The extracted phosphate rock from the non-magnetic tails of Sièrra Grande contains high residual iron (Fe; 5.80%), and by the mineralogical study, it may be concluded that there are three types of iron remained in phosphate rock.

(1) Small grain of iron minerals locked and included in apatite crystal

(2) Iron in chlorite minerals which is remained in phosphate rock as liberated or as locked with apatite

(3) Evenly distributed iron in apatite as is detected by X-ray micro-analyzer

The iron residue of the above (2) and (3) are observed only in phosphate rock of Sierra Grande and are not identified in phosphate rock from Grängesberg.

From the above mineralogical observations, it is suggested to decrease the residual iron in phosphate rock, following countermeasures should be considered;

(1) Extensive grinding and liberation of minerals

(2) Depressing the chlorite during apatite flotation

(3) No physical or chemical countermeasures will be feasible to decrease iron distributed evenly in apatite as is detected by X-ray micro-analyzer

2-7 Summary of Mineralogical Study

The investigation and study result of non-magnetic tails and extracted phosphate from Sierra Grande and Grängesberg are summarized in Table AIV-4 and Table AIV-5.

Table AIV-4 MINERALOGICAL STUDY RESULTS OF NON-MAGNETIC TAILS FOR PHOSPHATE ROCK CONCENTRATION

	HIPASAM Sierra Grande, Argentine	SSAB Grängesberg, Sweden
Major Minerals	Chlorite, Iron Minerals	Mica, Apatite, Amphibole, Fedlspar
Associated Minerals	Apatite, Quartz, Fedlspar, Mica, Garnet, Tourmaline	Iron Minerals, Quartz, Fluorite, Calcite, Garnet
Major Iron Minerals	Magnetite, Limonite, Hematite	Hematite, Magnetite
Major Phosphate Minerals	Fluorapatite, Hydroxyapatite Phosphate (Blue Colored) Phosphate (Brown Colored)	Fluorapatite
Liberated Apatite		
- 150/200 Mesh	-	Less than a Half
- 200/270 Mesh	Less than a Half	A Half
- 270/400 Mesh	A Half	More than a Half
Locked Minerals with Apatite	Iron Minerals Chlorite Phosphate (Blue Colored) Phosphate (Brown Colored)	Iron Minerals Mica, Amphibole, Quartz
Type of Locking	Simple to Complex Inclusion of Fine Iron Minerals in Apatite	Simple to Complex Inclusion of Fine Iron Minerals in Apatite
Iron Containing Minerals		
- Iron Minerals	Majority	Minority
- Chlorite	Majority	None
- Mica	Less (Muscovite)	Majority (Biotite, Philogopite)
- Amphibole	Minority	Majority
Chemical Analysis, %		
- Fe	27.53	10.48
- P	3.09	4.98
- P_2O_5	(7.08)	(11.41)
- CaO	3.93	17.41
- SiO_2	19.29	33.44
- Al_2O_3	14.23	7.05
Average Size, mm	0.028	0.049

Table AIV-5 MINERALOGICAL STUDY RESULTS OF PHOSPHATE ROCK EXTRACTED FROM NON-MAGNETIC TAILS OF IRON ORE CONCENTRATION PLANT

	HIPASAM Sierra Grande, Argentine	SSAB Grängesberg, Sweden
Major Minerals	Fluorapatite Hydroxyapatite	Fluorapatite
Associated Minerals	Chlorite Iron Minerals	Calcite Amphibole
Liberated Apatite	Majority	Majority
Locked Minerals with Apatite	Iron Minerals, Chlorite	Iron Minerals, Mica, Amphibole
Type of Locking	Complex, Inclusion of Fine Iron Minerals in Apatite	Complex, Inclusion of Fine Iron Minerals in Apatite
Elements in Apatite Detected by X-ray Microanalyzer	Majority; Ca, P Minority; Fe Not Detected; Mg	Majority; Ca, P Not Detected; Fe, Mg
Iron Containing Minerals	Iron Minerals, Chlorite, Mica	Iron Minerals, Mica, Amphibole
Chemical Analysis, %		
- Fe	5.80	1.10
- P	15.56	17.23
- P_2O_5	(35.65)	(39.48)
- CaO	44.30	52.50
- MgO	0.36	0.30
- F	1.50	2.80
- Cl	0.001	0.01
Average Size by Rosin-Rammler - Bennett Diagram, d', mm	0.022	0.054

3. Phosphate Rock Concentration Test

The phosphate concentration tests of non-magnetic tails from the iron ore concentration plant, HIPASAM, Sierra Grande, Argentine were carried out at laboratory and pilot plant in Japan. The representative sample of non-magnetic tails were taken at Sierra Grande on October 6, 1983 and flotation concentration and HGMS (high gradient magnetic separator) tests were undertaken to find out the most economical process for the concentration of phosphate rock.

The flotation process applied are the combination of a rougher flotation and multi-stage cleaner flotation with grinding, thickening, filtration and drying for the concentration of phosphate rock and for the removal of iron minerals from the final product.

Based upon the concentration tests and the mineralogical study, the basis of the conceptual design of the phosphate rock concentration plant is developed for the techno-economic analysis of the project.

During the cource of the tests, it was found that scavenger flotation, desliming, reverse flotation and the combination of magnetic separation are not so effective nor economical as industrial project.

3-1 Rougher Flotation

The objectives of the rougher flotation is to reduce the amount of rougher concentrate while keeping high recovery of phosphate minerals, therefore it is a minor objective to remove the iron minerals in the rougher concentrate.

The target of the recovery of P_2O_5 and iron minerals in the rougher concentrate are considered 90 and 35%, respectively. As was confirmed by the mineralogical study, the liberation of each minerals by grinding is the most important during the rougher flotation as well as during cleaner flotation.

At rougher flotation, following key operating conditions were studied;

- Type of Apatite Flotation Collector
- Grinding of Non-Magnetic Tails
- Selection of Optimum pH Condition
- Type of Depressant
- Type of Dispersant

(1) Collectors

The type of apatite flotation collectors tested are as follows;

- AP #845:	AERO PROMOTOR, Sulfonate of Petroleum Derivertives, ACC, the USA
- ETOL FT-A:	Raw Oleic Acid, Anan Koryo, Japan
- HARTLE:	Raw Oleic Acid, Anan Koryo, Japan
- #204:	Oleic Acid, Anan Koryo, Japan
- BS-130 TF:	Lilaflot, Anionic Derivertives of Fatty Acids, KenoGard AB, Sweden
- OS-130 TF:	Lilaflot, Anionic Derivertives of Fatty Acids, KenoGard AB, Sweden
- 730 F:	Lilaflot, Anionic Derivertives of Fatty Acids, KenoGard AB, Sweden

(2) Grinding

The grinding of the non-magnetic tails were carried out for the liberatin of apatite from iron minerals and chlorite and also for the cleaning and renewing the crystal surface of the non-magnetic tails. Grinding time were changed from 0.0 to 30.0 minutes to find out the optimum grinding conditions.

(3) pH Condition

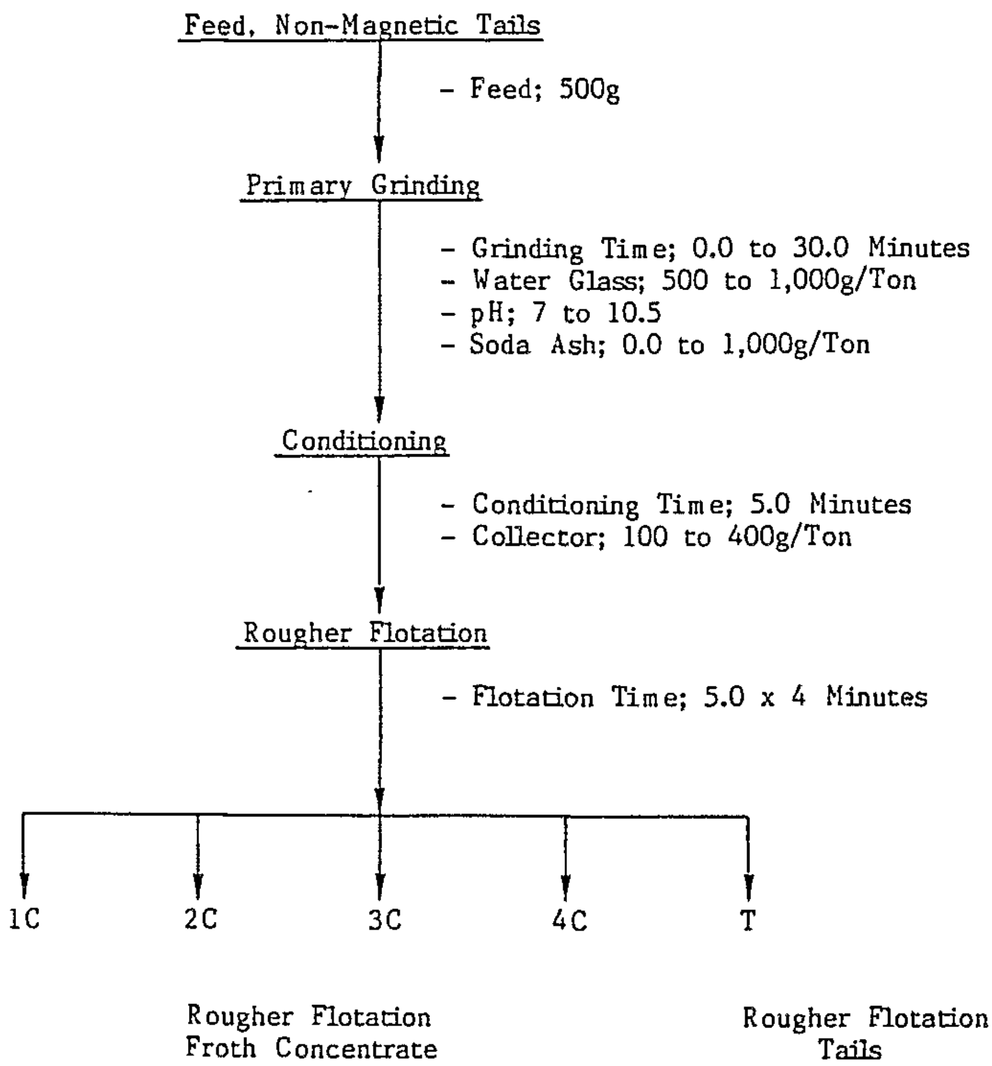
The pH condition during grinding and rougher flotation were tested at the pH of 7.0 to 10.5. Sodium hydoxide and soda ash are used to adjust the pH range of the flotation conditions. Gnerally 1,000g of soda ash is added per 1.0 Ton of feed non-magnetic tails as conditioner at first of operation.

(4) Dispersant and Depressant

In the rougher flotation, water glass is added for the dispersing the minerals and also for the depressing the iron minerals flotation. The dosage range tested is from 0.0 to 1,000g per 1.0 Ton of feed non-magnetic tails.

(5) Flow Sheet of Rougher Flotation

Basic Flow of the rougher flotation test carried out is illustrateed as follows;



(6) Test Results of Rougher Flotation

The test results of the rougher flotation are summarized hereunder;

The optimum separation for rougher flotation of P_2O_5 and iron are achieved when using the collector of Lilaflot BS-130TF. It is noted that the selectivity is better for Lilaflot OS-130TF, however the P_2O_5 recovery is lower, and the recovery of P_2O_5 is relatively high for HARTLES but the entrainment of iron minerals is also high. Lilaflot is an anionic delivertives of fatty acid which carboxy groups can form bonds with alkali earth minerals. The water repellent part is hydrocarbon with 8 to 22 carbon atoms which is joint to the carboxyl group through an intermediate linkage.

The relative flotation characteristics of the tested collectors are compared to show the P_2O_5 recovery and selectively.

flotation Collectors	Rougher flotation Concentrate	
	P2O5 Recovery	Iron Entrainment
- AP #845	35%	17%
- ETOL FT-A	57	40
- HARTLE	75	35
- # 204	52	22
- OS-130 TF	87	25
- BS-130 TF	95	35

The pH range of 10 is the most efficient for the collector of Lilaflot BS-130 TF, and the addition of soda ash as conditioner and water glass as dispersant and iron depressant are effective.

The grinding of feed is effective to increase the recovery of P_2O_5 but at a same time, the entrainment of iron minerals are also increased, therefore too much grinding is not preferable.

The typical test results of rougher flotation is that the recovery of concentrate in weight of 53.7%, P_2O_5 of 93.7% and Fe of 48.2% resulting the rougher flotation concentrate with 12.6% of P_2O_5 and 23.81% of Fe of quality.

3-2 Cleaner Flotation

The major objectives of the cleaner flotation is to further concentrate the rougher flotation concentrate to obtain product phosphate rock with high P_2O_5 and low iron contnet.

The main minerals of rougher flotation concentrate are apatite, iron minerals and chlorite which are partially liberated but mostly locked each other. Therefore the regrinding is required before cleaner flotation.

The flotation characteristics of apatite and chlorite are similar, especially in zeta potentials of crystal surface, therefore it is technically difficult to separate completely these two minerals by normal flotation or by reverse flotation. The specific objective of the cleaner flotation is, therefore to find out the optimum conditon for depressing the chlorite flotation. The flotability by anionic flotation collector is in the order of apatite, chlorite and iron minerals, and if the separation of apatite and chlorite is achieved the iron minerals are also separated from apatite.

The optimum conditions for cleaner flotation is seeked by using the same collector as is used for rougher flotation. The degree of grinding, the type of depressant and stage of recleaning steps are major items for the tests. Following type of depressant were tested;

- Water Glass
- Water Glass plus Dextrine
- Water Glass plus Starch (Wheat)
- Water Glass plus Starch (Sweet Potato)
- Water Glass plus Starch (Corn)
- Water Glass plus Quebracho
- Water Glass plus Sodium Hexametaphosphate

The dosage of water glass tested is from 100 to 250g/Ton of feed and that of dextrine or starch is from 10 to 50g/Ton of feed.

(1) Flow Sheet of Cleaner Flotation

Basic flow of the cleaner flotation test carried out is illustrated as follows:

Feed, Froth Concentrate of Rougher Flotation

↓
- Feed; 500g

Secondary Grinding

↓
- Grinding Time; 5 Minutes
- NaOH; 400g/Ton, pH; 10.1
- Depressant; 250g/Ton

Conditioning

↓
- Conditioning Time; 5 Minutes
- Collector; 0.2g/Ton x 4
- Depressant; 0.2g/Ton x 4

1st Cleaner Flotation

↓
- Flotation Time; 17 Minutes
- Water Glass; 250g/Ton
- Collector; 40g/Ton, Depressant; 20g/Ton

2nd Cleaner Flotation

↓
- NaOH; 100g/Ton
- Water Glass; 250g/Ton
- Collector; 10g/Ton, Depressant; 10g/Ton

3rd Cleaner Flotation

↓
- NaOH; 100g/Ton
- Water Glass; 250g/Ton
- Collector; 10g/Ton, Depressant; 10g/Ton

4th Cleaner Flotation

↓
- NaOH; 100g/Ton
- Water Glass; 250g/Ton

5th, 6th Cleaner Flotation

↓
- NaOH; 100g/Ton
- Water Glass; 250g/Ton

Product, Phosphate Rock, Flotation Concentrate

(2) Test Results of Cleaner Flotation

The batch wise depressant tests confirm that the addition of water glass plus starch or dextrine is highly effective for removing iron contents in froth concentrate and the addition of quebracho or sodium hexametaphosphate is less effective. The most effective combination is water glass plus dextrine for iron removal.

Upto seven stages of cleaner flotation tests were carried out and was found that from the industrial standpoint of view five stage flotation is the most practical.

The typical test results of cleaner flotation is shown as follows;

		Cleaner Flotation Performance				
		Analysis, %		Distribution, %		
		Fe	P2O5	Weight	Fe	P2O5
Imput;						
- Rougher Flotation Concentrate	(a)	19.69	16.88	100	100	100
	(b)	24.63	11.73	100	100	100
Output;						
- Cleaner Flotation Concentrate, Phosphate Rock	(a)	4.42	36.09	31.2	7.0	66.7
	(b)	5.07	36.55	19.3	4.0	60.2

It is possible to reduce iron content down to 4.0% by five stage cleaner flotation and the hypothetial extrapolation to zero yield of P_2O_5 with the lowest residual iron content, the minimum iron in the phosphate rock by flotation concentration is found to be 2.4% in terms of Fe.

3-3 Flow Sheet and Performance of Phosphate Rock Concentration by Flotation

Based upon the experimental test results of rougher and cleaner flotation the conceptual flow sheet of phosphate rock concentration plant are developed.

The flow scheme is the integration of various processes to obtain optimum performances;

- Primary Thickener ... Non-magnetic tails is to be concentrated to obtain higher pulp concentration for grinding
- Primary Grinding ... Large sized ore in the non-magnetic tails are ground
- Rougher Flotation ... Separation of iron minerals with highest recovery of P_2O_5
- Middle Thickener ... Concentration of rougher flotation is to be concentrated for grinding
- Secondary Grinding ... Liberation of apatite crystal from iron minerals and chlorite
- Cleaner Flotation ... Flotion of rougher flotation froth and depressing chlorite and iron minerals
- Final Thickener, Filter and Dryer ... Separation of water to produce by dry solid phosphate rock

The schematic flow of the phosphate rock concentration plant is shown in Figure AIV-2, and the concentration performance by rougher flotation and cleaner flotation is shown in Table AIV-6 which is utilized for the conceptual design of the phosphate rock concentration plant. The specification of product phosphate rock is shown in Table AIV-7. The consumption of flotation chemicals is estimated as follows:

- Flotation Collector	3.56 kg/Ton of Phosphate Rock
- Water Glass	8.91
- Dextrine	0.07
- Soda Ash	9.05

For the evaluation of the product phosphate rock as a raw materials for the production of phosphate fertilizers, the representative sample of 15.0kg are produced for various testings.

Figure AIV-2 CONCEPTUAL FLOW SCHEME FOR PHOSPHATE ROCK FLOTATION CONCENTRATION PLANT

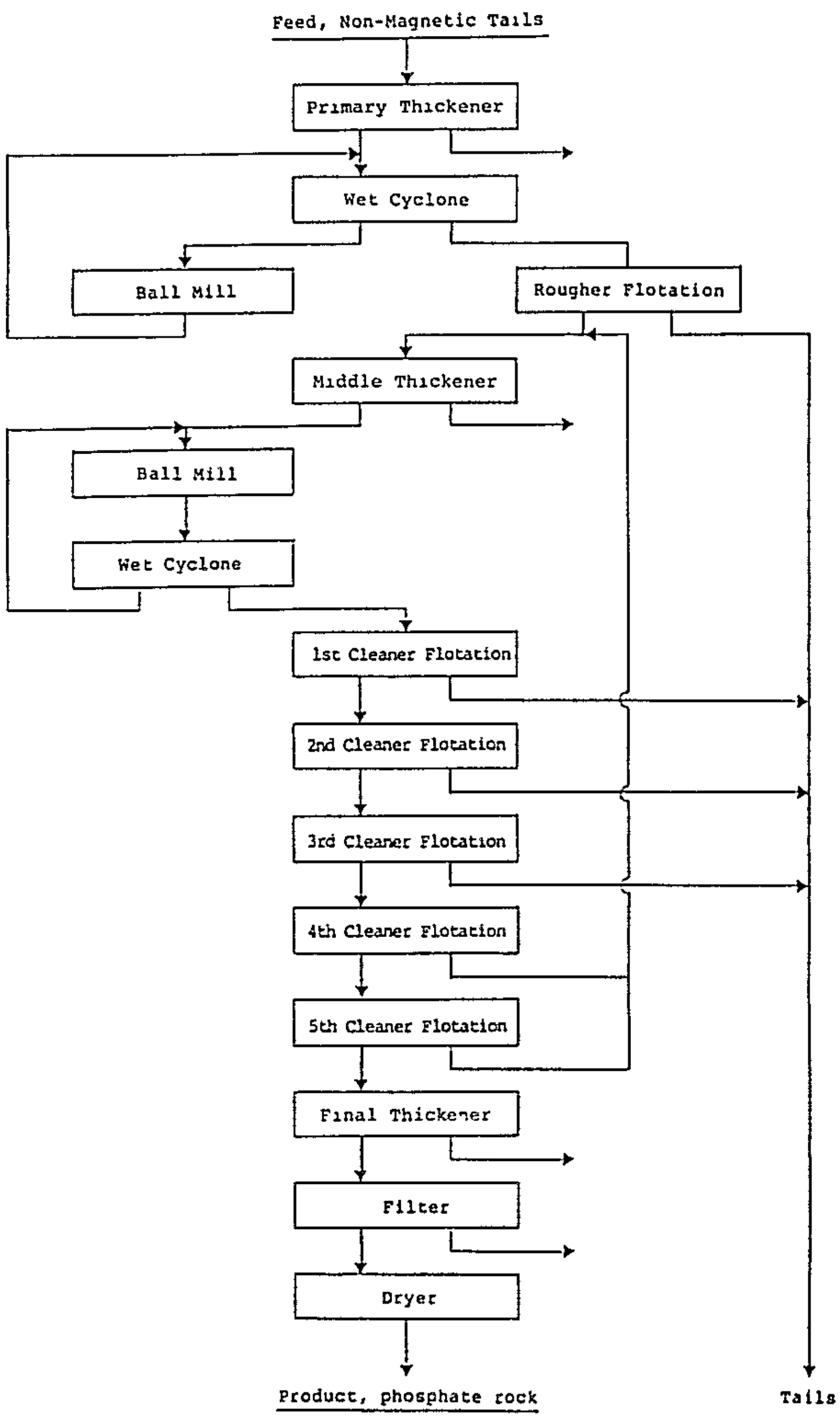


Table AIV-6 CONCENTRATION OF PHOSPHATE ROCK BY FLOTATION

Fraction	Performance				
	Analysis, %		Recovery, %		
	Fe	P_2O_5	Weight	Fe	P_2O_5
Inputs;					
Non-Magnetic Tails	27.50	7.08	100.00	100.00	100.00
Outputs;					
Design Basis,					
-Phosphate Rock	5.80	35.65	11.02	2.32	55.50
-Tails	30.18	3.54	88.98	97.68	44.50
Range of Test Results,					
(H)-Phosphate Rock	5∓0.2	36±0.2	10.80	2.00	55±2
-Tails	30.20	3.60	89.20	98.00	45∓2
(L)-Phosphate Rock	6∓0.2	35±0.2	11.90	2.60	59±2
-Tails	30.40	3.30	88.10	97.40	41∓2
Flotation Extrapolation,					
-Phosphate Rock	2.40	41.02	0.00	0.00	0.00
-Tails	27.50	7.08	100.00	100.00	100.00

Notes: 1) Non-magnetic tails of the iron concentration plant, HIPASAM, Sierra Grande, Argentine is treated at grinding, rougher and five stage cleaner flotation using anionic fatty acid derivatives for flotation collector.

2) The concentration tests were carried out at the Technical Research Center of Nippon Mining Co., Ltd., Japan.

Table AIV-7 *ANALYSIS OF PHOSPHATE ROCK EXTRACTED FROM IRON ORE CONCENTRATION* NON-MAGNETIC TAILS OF HIPASAM, SIERRA GRANDE, ARGENTINE

(1) CHEMICAL ANALYSIS

As Element	Weight Percent	As Oxide	Weight Percent	Equivalency for 100g Sample
P	15.56%	P_2O_5	35.65%	(-) 1.507
C (Carbonate)	0.09	CO_2	0.33	(-) 0.015
F	1.50	F	1.50	(-) 0.079
Cl	0.01	Cl	0.01	(-) 0.0005
OH	-	OH	(3.88)	(-) (0.2285)
S (Total)	-	S and Oxides	-	(-) -
S (Sulfide)	0.48	S	0.48	(-) 0.030
S (Sulfate)	-	SO_3	-	(-) -
Si	1.98	SiO_2	4.24	(-) 0.141
Fe (Total)	5.80	Fe Oxides	7.67	(+) 0.233
Fe (II)	4.36	FeO	(5.61)	(+) (0.156)
Fe (III)	1.44	Fe_2O_3	(2.06)	(+) (0.077)
Al	1.46	Al_2O_3	2.06	(+) 0.162
Mn	-	MnO	-	(+) -
Ca	31.66	CaO	44.30	(+) 1.580
Mg	0.22	MgO	0.36	(+) 0.018
Na	0.15	Na_2O	0.20	(+) 0.006
K	0.07	K_2O	0.08	(+) 0.002
Others	-	Others	-	-
Free Moisture	0.14	Free Moisture	0.14	-
Organics	-	Organics	-	-
Ignition Loss	1.68	Ignition Loss	1.68	
Total	65.95	Sub-total	102.58	(-) 2.001
		Adjustment for F	(-) 0.63	(+) 2.001
		Total	101.95	(+) 0.000

(2) PHYSICAL PROPERTY

Color		Gray
Size Distribution (Tyler Mesh and Millimeter)		
(+) 400 Mesh	(0.0370 mm)	15.9%
(+) 468.4	(0.0316)	18.4
(+) 677.8	(0.0219)	36.1
(+) 993.3	(0.0149)	52.5
(+) 1,309.7	(0.0113)	64.5
(-) 1,309.7	(0.0113)	35.4
		100.0
Density		3.27
Bulk Density - Packed		1.67
- Loose		1.27
Angle of Reponse		43.0°
Free Moisture of Filter Cake, %		13.0
Specific Surface Area, cm^2/gr		2,770

(3) *FERTILIZER PROPERTY*

	Weight Percent	Solubility Percent
Total P_2O_5	35.65%	100.0%
Nitric Acid Soluble P_2O_5	35.60	99.9
Hydrocholoric Acid Soluble P_2O_5	35.11	98.5
Citric Acid Soluble P_2O_5	7.96	22.3
Formic Acid Soluble P_2O_5	5.69	16.0
Ammonium Citrate Soluble (AV) P_2O_5 (Neutral)	0.00	0.0
Water Soluble P_2O_5	0.00	0.0

Notes: - Sample tails (Fe=27.53%, P_2O_5=7.08%) were taken on October 6, 1983 at HIPASAM and concentration test and analysis were made at NIKKO Consulting and Engineering Co. Ltd., Japan in January, 1984. Recovery of P_2O_5 is 55.5%. Fertilizer property was determined at Nissan Chemical Industries, Ltd., Japan in March, 1984.
- Ignition loss is measured by heating at 900°C for 0.5 hours.
- Free moisture is measured by heating at 105°C for 5.0 hours.
- (OH) is estimated to keep balanced equivalency.

3-4 High Gradient Magnetic Separation

From the mineralogical study and also from the flotation test results, it is clear that the apatite crystals are closely combined with iron minerals or with chlorite which contains iron element as consituent. It is also considered that the concentration of apatite or separation of iron minerals and chlorite from apatite to obtain high quality product phosphate rock is possible by the liberation of each minerals at first and then by some separation process.

Flotation is of course one of the most efficient process but another possibility is to utilize magnetic separation. From the preliminary trials, the conventional magnetic separation is found not so effective for the separation. Therefore, to reduce iron content in the phosphate rock, application of the high gradient magnetic separation (HGMS) using the flotation concentrate of the non-magnetic tails, HIPASAM, Sierra Grande, Argentine as raw material feed is tested.

The apparatus used is the cyclic type HGMS(10-15-20), of Sala Magnetics, Inc., USA and the magnetic fields of 0.0, 1.0, 5.0 and 20.0 kilo gauss/cm are applied.

The test results are summarized in Table AIV-8 for showing analysis and recovery performance of each magnetics and non-magnetics. The highest reduction of iron is realized when 20.0 kilo gauss/cm magnetic field is applied and the product phosphate rock of 39.55% P_2O_5 and 1.84% Fe is obtained. However the recovery of P_2O_5 is 39.7% during HGMS concentration or 22.0% during overall concentration of flotation and HGMS concentration processes.

From these test results it is concluded that HGMS is highly effective to remove iron from phosphate rock down to 1.84% but for the industrial application, the recovery of P_2O_5 in phosphate rock is not satisfactory.

Table IV-8 CONCENTRATION OF PHOSPHATE ROCK BY HIGH GRADIENT MAGNETIC SEPARATORS

Fraction		Magnetic Field, Kilo Gauss	Performance				
			Analysis, %		Recovery, %		
			Fe	P_2O_5	Weight	Fe	P_2O_5
F-5,	Feed Phosphate Rock	0.0	5.74	36.00	100.0	100.0	100.0
N-01,	Non-Magnetics	1.0	4.88	36.54	86.3	73.3	87.6
M-01,	Magnetics	1.0	11.11	32.52	13.7	26.6	12.4
N-05,	Non-Magnetics	5.0	2.87	38.83	63.5	31.7	68.5
M-05,	Magnetics	5.0	10.52	30.15	22.8	41.7	19.1
N-20,	Non-Magnetics	20.0	1.84	39.55	36.2	11.6	39.7
M-20,	Magnetics	20.0	4.21	37.97	27.3	20.1	28.8

Notes:
1) Feed phosphate rock is flotation concentration product by rougher and five stage cleaner from non-magnetic tails of HIPASAM, Sierra Grande, Argentine which P_2O_5 recovery is 55.5%. The particle size is 30.4% for (+)0.02 mm and 69.[illegible]% for (-)0.02 mm fraction.

2) Fraction of N-01 is fed to obtain N-05 and M-05 and fraction N-05 is further fed to obtain N-20 and M-20.

3) The concentration tests were carried out at Nittetsu Mining Co., Ltd., Japan using the cyclic type HGMS (10-15-20), Sala Magnetics, Inc., USA.

4) Applied magnetic field is measured in terms of Gauss/cm.

Annex V

PROJECT DESCRIPTION

ANNEXURES

Annex V-1 Project Description
Communication
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Annex V-2 Transducer [illegible]
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Annex V-3 Mixed Signal [illegible]
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Annex V-4 Digital [illegible]
pp. [illegible]

Annex V-5 Trial [illegible]
pp. [illegible]

Annex V-6 [illegible]
[illegible]
pp. [illegible]

Annex V-7 [illegible]
[illegible]
pp. [illegible]

Annex V-8 [illegible]
[illegible]
pp. [illegible]

Annex V-1

PROJECT DESCRIPTION FOR PHOSPHATE ROCK CONCENTRATION PLANT

PC - 1 ... PR

Phosphate Rock Production Form Non-Magnetic Tails at HIPASAM, Sierra Grande, Río Negro, Argentine

PROJECT DESCRIPTION FOR PHOSPHATE ROCK CONCENTRATION PLANT
PC - 1 ... PR

Phosphate Rock Production from Non-Magnetic Tails
at HIPASAM, Sierra Grande, Río Negro, Argentine

1. Project Outline

The proposed phosphate rock concentration plant project is to produce phosphate rock (P_2O_5: 35.65%, Fe: 5.80%) by flotation process, using non-magnetic tails as raw material which is a by-product and now discarded at the iron ore concentration plant of HIPASAM, Sierra Grande, Argentine.

The phosphate rock concentration plant will take non-magnetic tails from the primary and secondary magnetic separators at the existing iron ore concentration plant of HIPASAM. The phosphate rock concentration plant will also produce tails which will be further processed at the existing iron ore concentration plant or will be discarded as is practised at HIPASAM at present.

The design capacity of the proposed plant is 336.7 TPD of phosphate rock in bulk powder by using 3,103.1 TPD of non-magnetic tails as dry solid. The product phosphate rock will be transported to the phosphate fertilizer plant for further processing and up-grading.

The experimental tests of the phosphate rock concentration process developments were carried out at a small scale test (15.0 kg of phosphate rock production) at Nikko Consulting and Engineering Co., Ltd., Japan and the study results were incorporated into the conceptual design of the proposed concentration plant as is explained hereunder.

The proposed plant will be located in the plant site of the existing iron ore concentration plant of HIPASAM, Sierra Grande, Río Negro, therefore the additional requirements for utility and auxiliary facility are rather marginal. The major facility in the plant is as follows:

Process Plant;	
-Phosphate Rock Concentration Plant	336.7 TPD
Utility Plant;	
-Electric Power Distribution	6,000.0 kWh/h
-Raw Water Supply	50.0 TPH
-Others	-
Storage and Material Handling Facility;	
-Phosphate Rock Storage	5,000 Ton
-Phosphate Rock Loading	80 TPH
Auxiliary Facility;	
-Administration Building	500 m^2
-Maintenance Shop and Storage	1,000
-Others	-

The total area for the project site is 40,000m^2(200m x 200m).

2. Plant Description

The outline of the process plant, utility plant, storage and material handling facility, and auxiliary facility in the phosphate rock concentration plant is described hereunder.

The raw material feed rate and its specification are determined by taking into consideration of the operating conditions at present and in the future when the iron ore concentration plant is operated at full capacity. The available data of feed tonnage of non-magnetic tails, which is the expected value at full operation, is 2,880 TPD as solid material with P_2O_5 concentration of 7.63%, which is calculated from the long-term analysis of past performance at HIPASAM. While the phosphate concentration tests were carried out for the non-magnetic tails taken on October 6, 1983 as representative samples (sample weight, dry; 500kg, P_2O_5 concentration; 7.08%) and the P_2O_5 recovery of 55.5% with P_2O_5 concentration of 35.65% in the product phosphate rock were obtained as basis of the conceptual design. To establish the design basis of the plant, it is assumed that the total available P_2O_5 in the non-magnetic tails is constant within a range of operational fluctuation of the feed rate of non-magnetic tails and its P_2O_5 concentration.

Therefore, it is considered reasonable to assume that the daily P_2O_5 in non-magnetic tails and in recovered phosphate rock are 219.7 and 121.9 TPD, respectively. For allocation of handling losses in the plant, as the basis of the plant design, the production capacity of phosphate rock and its P_2O_5 are assumed 336.7 and 120 TPD, respectively (recovery of P_2O_5; 54.64%). The adjusted feed rate of non-magnetic tails is 3,103.1 TPD instead of 2,880 TPD.

The raw material feed condition of the non-magnetic tails are shown in Table AV-1-1.

Table AV-1-1 RAW MATERIAL CONDITIONS FOR PHOSPHATE ROCK CONCENTRATION PLANT

1. Source: Non-Magnetic Tails from Magnetic Separator (Between 828/9 to 850) at Iron Ore Concentration Plant, HIPASAM, Sierra Grande, Rio Negro, Argentine

2. Specification:

-Analysis, Dry Weight	
Fe	27.53%
Fe (II)	13.78
Fe (III)	13.75
K_2O	0.67
Na_2O	0.23
MgO	1.14
CaO	3.93
Al_2O_3	14.23
P	3.09
P_2O_5	(7.08)
SiO_2	19.29
S	2.28
F	0.23
Cl	0.001
CO_2	0.16
-Size Distribution	
(+) 0.2 mm	5.0%
(+) 0.1	15.0
(+) 0.05	35.0
(+) 0.02	55.0
(+) 0.01	70.0
(+) 0.005	75.0
(+) 0.002	82.0
(-) 0.002	18.0
-Conditions	
Pressure	1.0 ata
Temperature	10.0°C
Solid Content	4.0%
Water Content	96.0
Specific Gravity	1.03

2-1 Phosphate Rock Concentration Plant

(1) Introduction

The phosphate rock concentration plant is to produce 336.7 TPD of phosphate rock by using non-magnetic tails from the existing iron ore concentration plant of HIPASAM, Sierra Grande.

The principles of the process plant are dewatering at first of non-magnetic tails for extensive grinding, flotation separation of phosphate rock from iron ores, and then separation of water at thickener, filter and dryer to produce dry bulk phosphate rock.

The process plant returns the water recovered from the thickener to the iron ore concentration plant and also tails which will be fed back to the iron ore concentration plant or discarded at tailing pond of Laguna Blanca in Sierra Grande.

The process plant consists of three major sections:

- -Thickener and Grinding Plant
- -Flotation Concentration Plant
- -Filtration and Drying Plant

The dried phosphate rock will be shipped directly to the phosphate fertilizer plant or temporarily stored in the bulk warehouse.

(2) Process Description

(a) Thickener and Grinding Plant

The feed non-magnetic tails from the existing iron ore concentration plant is taken as 4.0% solid slurry in water through pipeline and fed into a raw material thickener with a 75 meter diameter. The settling velocity of tails with average diameter of 0.028mm is observed as hourly 0.51 meter. The overflow liquor is returned to the iron ore concentration plant and underflow spigot of 55.0% solid slurry is obtained.

The spigot is processed at wet cyclone separators from which under sized tails are fed to the flotation plant while over sized tails are fed at ball mill for extensive wet grinding.

The work index of grinding is measured 12.0 kWh/short ton of tails and the mill product is of particle size with 0.04 mm at 80% cumulative size distribution. The ground tails are also fed to the flotation plant.

(b) Flotation Concentration Plant

The ground tails from the thickener and grinding plant are processed at the flotation concentration plant which consists of rougher flotation, middle thickener, ball mill, first cleaner, second cleaner, third cleaner, fourth cleaner, fifth cleaner and final thickener to produce concentrated phosphate rock slurry.

The recycle circuits in the plant are that the over size from the ball mill is fed back to the ball mill and the tails from the fourth and fifth cleaner flotation are fed back to the middle thickener and ball mill for further processing.

The flotation conditions at rougher and cleaner are that the feed pulp concentration is adjusted 30% solid content and flotation retention time of 10.0 to 15.0 minutes, respectively.

The work index of grinding at the ball mill is measured 17.5 kWh/short ton to obtain 0.03 mm size particle at 80% cumulative size distribution.

The solid content of tails are from 16.0 to 24.0% and of froth concentrates are 40.0% which is adjusted to 30% by adding water for next flotation processing.

The flotation collector chemicals of anionic fatty acid derivatives; the depressants of water glass and starch, and the pH modifier of soda ask are added during the rougher and cleaner flotation steps. The number of lotation cells required is 60 units of 3.3 m^3 volume and 32 units of 1.4 m^3 volume. The diameter of thickener is 12.0 meter for the middle thickener and 7.5 meter for the final thickener. The solid content of the final thickener bottom is 50% which is fed to the filtration and drying plant. The water glass and soda ash are added as dispersant, too.

The tails from the plant is also treated at the tail thickener with 30 meter diameter.

(c) Filtration and Drying Plant

The phosphate rock slurry of 50% concentration from the final thickener is further processed at the disk filters. The filter cake with 13 % moisture content is directly fed to the rotary drum dryer where natural gas fired hot air is co-currently fed to obain dry phosphate rock powder with moisture content of less than 3.0%. The phosphate rock in the dryer exhaust gas is recovered at cyclone separator and mixed with dryer product for further cooling in rotary drum cooler and then sent to the product bulk storage and loading facility.

(3) Product Specification

The plant is to produce 336.7 TPD of dry powder phosphate rock in bulk and 2,766.4 TPD of tails under normal operating conditions.

The brief specification is as follows:

Phosphate Rock;

-Daily Production, Wet	336.7 TPD
-Analysis	
-P_2O_5	35.65 %
-CaO	44.30
-F	1.50
-Fe	5.80
-Free Moisture	0.14
-Ignition Loss	1.68
-Condition	
-Size Distribution	
(+) 0.0316 mm	18.4 %
(+) 0.0149	52.5
(+) 0.0113	64.5
-Bulk Density	1.67
-Angle of Repose	43.0°C
-Temperature	40.0
-Pressure	1.0 ata

Tails;

-Daily Production, Dry	2,766.4 TPD
-Analysis	
-P_2O_5	3.60 %
-Fe	30.18
-Condition	
-Size Distribution	
(+) 0.0316 mm	35.0 %
(+) 0.0149	85.0
-Free Moisture	50.0
-Temperature	10°C
-Pressure	1.0 ata

The detailed specification of phosphate rock is shown in Table AV-1-2.

Table AV-1-2 ANALYSIS OF PHOSPHATE ROCK EXTRACTED FROM IRON ORE CONCENTRATION NON-MAGNETIC TAILS OF HIPASAM, SIERRA GRANDE, ARGENTINE

(1) CHEMICAL ANALYSIS

As Element	Weight Percent	As Oxide	Weight Percent	Equivalency for 100g Sample
P	15.56%	P_2O_5	35.65%	(-) 1.507
C (Carbonate)	0.09	CO_2	0.33	(-) 0.015
F	1.50	F	1.50	(-) 0.079
Cl	0.01	Cl	0.01	(-) 0.0005
OH	-	OH	(3.88)	(-) (0.2285)
S (Total)	-	S and Oxides	-	(-) -
S (Sulfide)	0.48	S	0.48	(-) 0.030
S (Sulfate)	-	SO_3	-	(-) -
Si	1.98	SiO_2	4.24	(-) 0.141
Fe (Total)	5.80	Fe Oxides	7.67	(+) 0.233
Fe (II)	4.36	FeO	(5.61)	(+) (0.156)
Fe (III)	1.44	Fe_2O_3	(2.06)	(+) (0.077)
Al	1.46	Al_2O_3	2.06	(+) 0.162
Mn	-	MnO	-	(+) -
Ca	31.66	CaO	44.30	(+) 1.580
Mg	0.22	MgO	0.36	(+) 0.018
Na	0.15	Na_2O	0.20	(+) 0.006
K	0.07	K_2O	0.08	(+) 0.002
Others	-	Others	-	-
Free Moisture	0.14	Free Moisture	0.14	-
Organics	-	Organics	-	-
Ignition Loss	1.68	Ignition Loss	1.68	
Total	65.95	Sub-total	102.58	(-) 2.001
		Adjustment for F	(-) 0.63	(+) 2.001
		Total	101.95	(+) 0.000

(2) PHYSICAL PROPERTY

Color		Gray
Size Distribution (Tyler Mesh and Millimeter)		
(+) 400 Mesh	(0.0370 mm)	15.9%
(+) 468.4	(0.0316)	18.4
(+) 677.8	(0.0219)	36.1
(+) 993.3	(0.0149)	52.5
(+) 1,309.7	(0.0113)	64.5
(-) 1,309.7	(0.0113)	35.4
		100.0
Density		3.27
Bulk Density - Packed		1.67
- Loose		1.27
Angle of Reponse		43.0°
Free Moisture of Filter Cake, %		13.0
Specific Surface Area, cm^2/gr		2,770

(3) FERTILIZER PROPERTY

	Weight Percent	Solubility Percent
Total P_2O_5	35.65%	100.0%
Nitric Acid Soluble P_2O_5	35.60	99.9
Hydrocholoric Acid Soluble P_2O_5	35.11	98.5
Citric Acid Soluble P_2O_5	7.96	22.3
Formic Acid Soluble P_2O_5	5.69	16.0
Ammonium Citrate Soluble (AV) P_2O_5 (Neutral)	0.00	0.0
Water Soluble P_2O_5	0.00	0.0

Notes: - Sample tails (Fe=27.53%, P_2O_5=7.08%) were taken on October 6, 1983 at HIPASAM and concentration test and analysis were made at NIKKO Consulting and Engineering Co. Ltd., Japan in January, 1984. Recovery of P_2O_5 is 55.5%. Fertilizer property was determined at Nissan Chemical Industries, Ltd., Japan in March, 1984.
- Ignition loss is measured by heating at 900°C for 0.5 hours.
- Free moisture is measured by heating at 105°C for 5.0 hours.
- (OH) is estimated to keep balanced equivalency.

(4) Raw Material, Utility, Chemicals and Catalysts Consumption

The consumption at the phosphate rock concentration plant under normal operating conditions are as follows:

	Production and Consumption		
	Unit Production	Hourly	Daily
Production;			
-Phosphate Rock, Bulk, Ton	1.0000	14.029	336.7
-Tails, Ton	8.2162	115.267	2,766.4
-Recovered Water, Ton	213.58	2,996.337	71,912.1
Consumption;			
-Non-Magnetic Tails, Dry, Ton	9.2163	129.29	3,103.1
-Water in Tails, Ton	221.1918	3,103.10	74,474.4
-Raw Water, Ton	0.7566	10.60	254.4
-Electric Power, kWh	317.200	4,450.00	106,800.0
-Natural Gas, MMBTU-LHV	0.50	7.01	168.3
-Chemicals*			
-Flotation collector, Ton	0.00356	0.05	1.20
-Water Glass, Ton	0.00891	0.125	3.00
-Starch, Ton	0.00007	0.001	0.024
-Soda Ash, Ton	0.00905	0.127	3.05

* The consumption of chemicals are equivalent to US$12.293 (CIF Value)/Ton of Phosphate Rock at the date of base project cost estimate.

2-2 Utility Plants

The major utility plants required for the phosphate rock concentration plant are designed to have following capability:

	Facility Capacity	Normal Demand
Electric Power Distribution, kWh	6,000	4,750
Natural Gas Receiving, MMSCFD	1.0	0.3
Raw Water Distribution, TPH	50	11.0
Others	-	-

2-3 Storage and Material Handling Facility

The major facilities for raw materials, intermediates, and product receiving, storage, loading and other material handlings are designed to have following capacity:

	Facility Capacity	Normal Daily Requirement
Storage Facilities;		
-Phosphate Rock, Ton	5,000	336.7
-Phosphate Rock Loading, TPH	80	14.0
-Chemicals, Ton	700	7.0

2-4 Auxiliary Facilities

The major auxiliary facilities for the management of the production, maintenance and accommodation at the phosphate rock concentration plant is designed to have following specification;

	Facility Specifications
Administration Building	500 m^2
Laboratory	100
Maintenance shop	1,000
Others	-

3. Project Summary

The proposed phosphate rock concentration plant is to extract phosphate rock from non-magnetic tails of the iron ore concentration plant by flotation process.

3-1 Product Specification

The brief specification of the product and its production is summarized as below:

Product	Specification	Production, Ton Daily	Production, Ton Annual
Phosphate Rock	P_2O_5; 35.65%, Fe; 5.80%, Bulk	336.7	100,000

The limiting factor for the production of phosphate rock is the availability of the non-magnetic tails of HIPASAM, Sierra Grande, Río Negro. The total P_2O_5 in the non-magnetic tails is 219.7 TPD and the P_2O_5 will be recovered at yielding efficiency of 54.63% in the product phosphate rock.

3-2 Overall Consumption

The overall consumption of raw material, utility, chemicals for the proposed project is calculated for the financial analysis of the project which includes losses during storage, processing, loading and transportation of the product phosphate rock from Sierra Grande to the phosphate fertilizer as well as the consumption for utility and auxiliary facilities.

In these calculation, the by-product tails of phosphate rock concentration plant and return water are not credited for the financial analysis.

	Production and Consumption		
	Unit Product	Hourly	Daily
Production;			
-Phosphate Rock, Bulk Ton	1.0000	14.029	336.7
Consumption;			
-Non-Magnetic Tails, Dry, Solid	9.2163	129.29	3,103.1
-Raw Water, Ton	0.784	11.00	264.0
-Electric Power, kWh	338.58	4,750.00	114,000.0
-Natural Gas, MMBTU-LHV	0.55	7.72	185.2
-Chemicals, USD-1983	12.50	175.36	4,208.7

3-3 Overall Flow Block Diagram

The overall flow block diagram of the phosphate rock concentration plant showing process plant, utility and auxiliary facilities are illustrated in Figure AV-1-1.

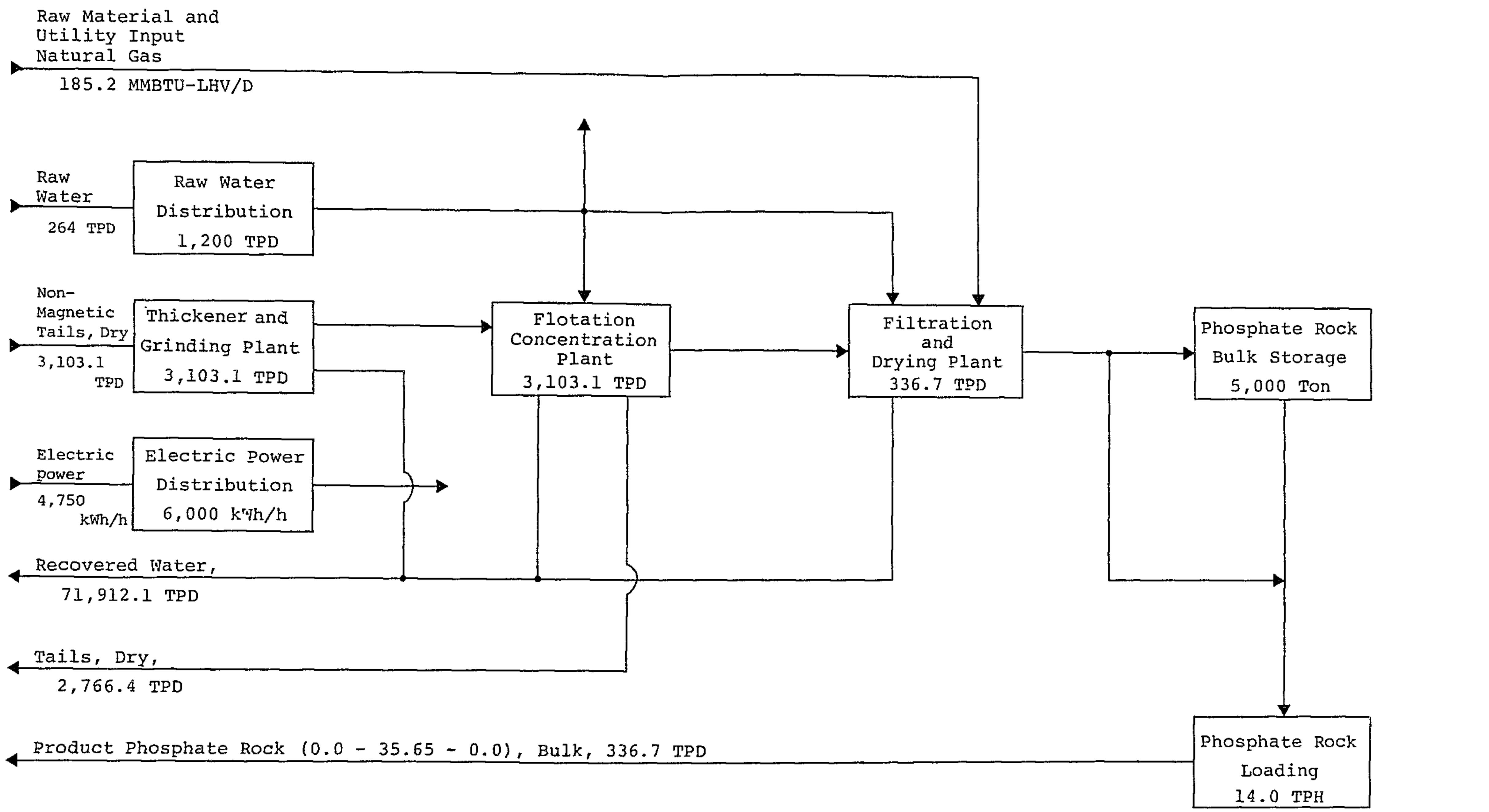


Figure AV-1-1

BLOCK FLOW DIAGRAM FOR PHOSPHATE ROCK CONCENTRATION

Project: PHOSPHATE ROCK CONCENTRATION PLANT ... PC-1

Feasibility Study: The Establishment of a Phosphate Fertilizer Plant in the Argentine Republic. Japan International Cooperation Agency. April, 1984

3-4 General Plot Plan

the general plot plan of the phosphate rock concentration plant showing location of each major facilities are illustrated in Figure AV-1-2. The total site area required is 40,000 m^2 (200m x 200m).

3-5 Organization and Personnel

The overall organizational and personnel for phosphate rock concentration plant project is illustrated in Table AV-1-3. The total number of personnel in the organization is 238 under normal operating conditions.

3-6 Investment Cost Estimate

The estimated investment cost for the construction of the phosphate rock concentration plant is illustrated in Table AV-1-4. The project is assumed to be started with the engineering works on January 1, 1987 and located in Sierra Grande, Río Negro, Argentine.

3-7 Project Implementation Schedule

The overall implementation schedule for the phosphate rock concentration plant project is illustrated in Figure AV-1-3. It takes 24 months for the mechanical completion and 26 months for the commencement of commercial production from the date of contract award for the plant construction.

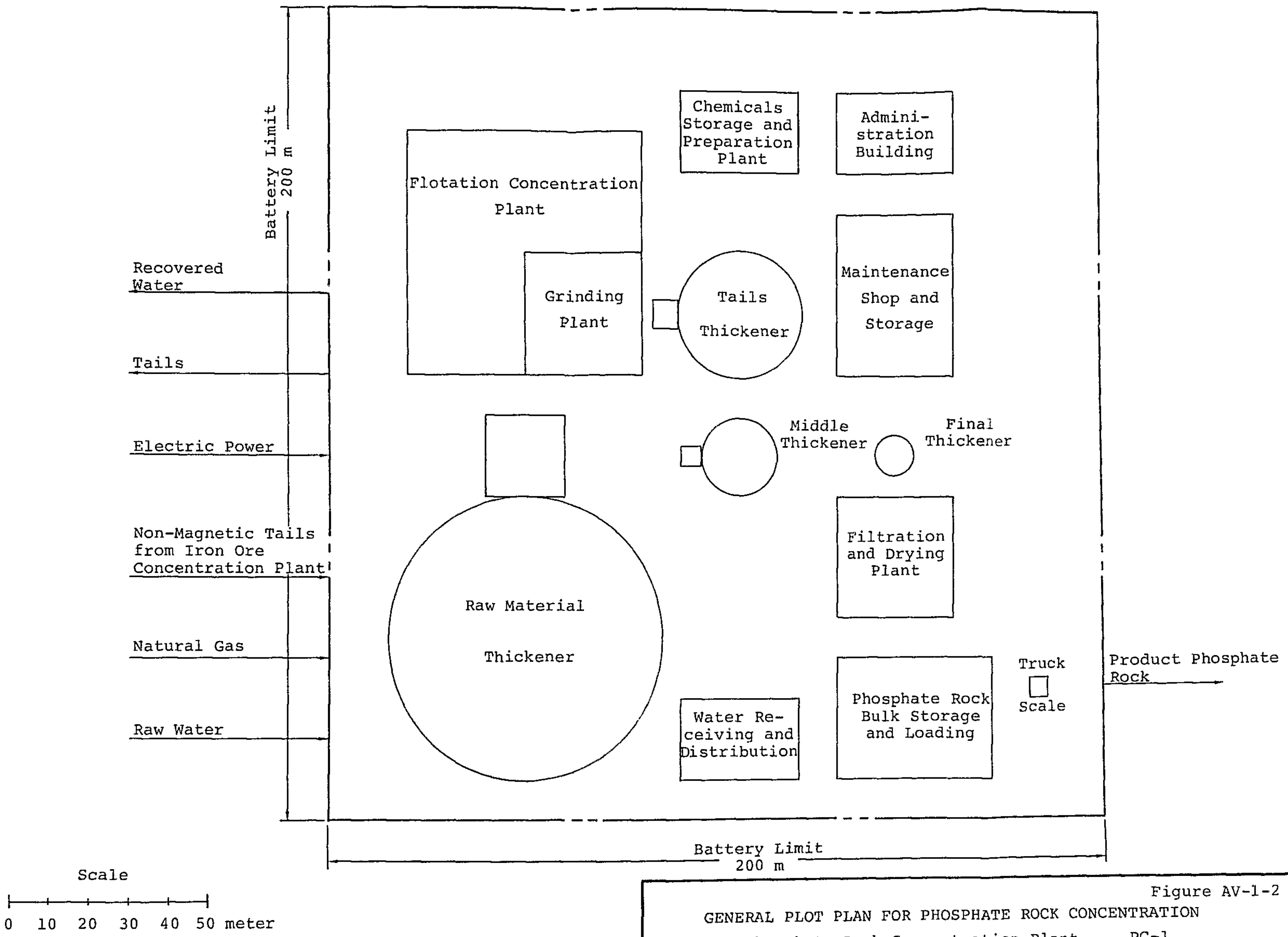


Figure AV-1-2

GENERAL PLOT PLAN FOR PHOSPHATE ROCK CONCENTRATION

Project: Phosphate Rock Concentration Plant ... PC-1

Feasibility Study: The Establishment of a Phosphate Fertilizer Plant in the Argentine Republic., Japan International Cooperation Agency, April, 1984

Table AV-1-3 ORGANIZATION AND PERSONNEL REQUIREMENTS

Feasibility Study: On the Establishment of a Phosphate Fertilizer Plant in the Argentine Republic
Project: Phosphate Rock Concentration Plant, PC-1
Product: Phosphate Rock, Bulk
Capacity: 100,000 TPY of Phosphate Rock (P_2O_5: 35.65%, Fe: 5.60%)
Location: Sierra Grane, Rio Negro, Argentine

	Organization for the Project	Managing Director, Director	General Manager, Manager	Senior Engineer and Officer	Supervisor, Foreman, Officer	Operator, Worker, Secretary	Total
1.	Head Office and Regional Sales Office - Buenos Aires	(6)	(2)	(3)	(4)	(4)	(19)
2.	Factory Head Office and Plant Factory Complex - Sierra Grande	(1)	(9)	(25)	(54)	(130)	(219)
2.1	Factory Director's Office	(1)	(1)	(2)	(4)	(4)	(12)
2.2	General Affair Department	(0)	(0)	(7)	(7)	(7)	(21)
	- Administration Section	0	0	1	1	1	3
	- Personnel Section	0	0	1	1	1	3
	- Financing/Accounting Section	0	0	1	1	1	3
	- Housing and Welfare Section	0	0	1	1	1	3
	- Security and Health Section	0	0	1	1	1	3
	- Leagal Section	0	0	1	1	1	3
	- Purchase and Product Sales Section	0	0	1	1	1	3
2.3	Production Department	(0)	(3)	(3)	(15)	(64)	(85)
	- Thickner/Grinding	0	1	1	5	16	23
	- Flotation Concentration	0	1	1	5	28	35
	- Filtration/Drying	0	1	1	5	20	27
2.4	Utility Department	(0)	(1)	(2)	(10)	(16)	(29)
	- Raw Water	0	1	1	5	8	15
	- Others	0	0	1	5	8	14
2.5	Maintenance and Inspection Department	(0)	(2)	(5)	(6)	(10)	(23)
	- Maintenance Management	0	1	1	1	1	4
	- Mechanical Section	0	1	1	1	4	7
	- Electrical Section	0	0	1	1	2	4
	- Instrumental Section	0	0	1	1	1	3
	- Civil Construction Section	0	0	0	1	1	2
	- Inventory Section	0	0	1	1	1	3
2.6	Product Handling Department	(0)	(1)	(1)	(4)	(14)	(20)
	- Storage Management	0	1	1	2	4	8
	- Product Loading	0	0	0	2	10	12
2.7	Technical and Development Department	(0)	(1)	(5)	(8)	(15)	(29)
	- Production Management	0	1	1	2	2	6
	- Development and Engineering Section	0	0	1	2	2	5
	- Analytical Laboratory	0	0	1	2	8	11
	- Training Section	0	0	1	1	1	3
	- Product Sales Services	0	0	1	1	2	4
3.	Total Personnel for the Project	7	11	28	58	134	238

Notes: 1) Additional contract for product loading and trasnportation from Sierra Grande to Bahia Blanca is assumed which costs are included in the product transportation cost for financial analysis.

2) During annual maintenance work for 35 days, additional maintenance supervisor and labor are contracted (Vendor specialist; 8, Inspector; 12, Laborer: 100, Total; 120 persons) whose costs are included in maintenance cost for financial analysis.

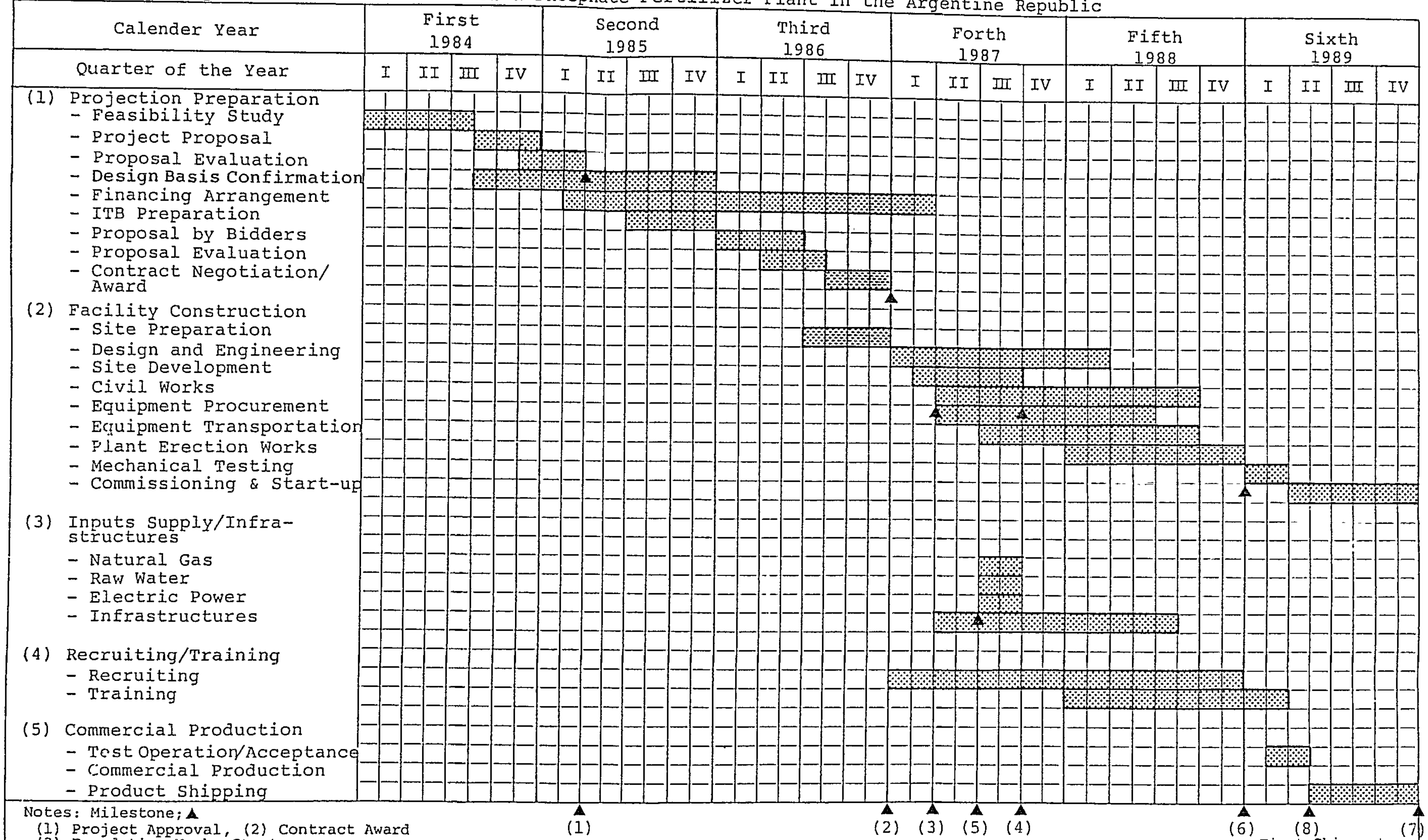
Table AV-1-4 PROJECT INVESTMENT COST ESTIMATE

Feasibility Study: On the Establishment of a Phosphate Fertilizer Plant in Argentine Republic
Project: Phosphate Rock Concentration Plant, PC-1
Product: Phosphate Rock, Bulk
Capacity: 100,000 TPY of Phosphate Rock (P_2O_5: 35.65%, Fe: 5.80%)
Location: Sierra Grande, Rio Negro, Argentine

		Project Investment Cost Estimate (USD, Million)		
		Foreign Currency Component	Local Currency Component	Total
1.	Land Acquisition	0.00	0.20	0.20
2.	Site Preparation	0.00	0.20	0.20
3.	Plant Direct Cost	9.24	15.69	24.93
3.1	Equipment and Materials, FOB	4.10	4.09	8.19
	(1) Thickner/Grinding Plant	1.23	1.02	2.25
	(2) Flotation Concentration Plant	1.15	1.05	2.20
	(3) Filtration/Drying Plant	0.20	1.20	1.40
	(4) Utility Plant	0.25	0.30	0.55
	(5) Storage and Material Handling Facility	0.15	0.80	0.95
	(6) Auxiliary Facility	0.12	0.72	0.84
3.2	Spare Parts, FOB	0.74	0.20	0.94
3.3	Catalysts and Chemicals, FOB	2.10	0.40	2.50
3.4	Civil Materials, CIF	1.25	5.87	7.12
3.5	Construction and Erection Labor	1.05	5.13	6.18
4.	Construction and Erection Equipments	0.15	0.60	0.75
5.	Freight, Insurance & Local Handling	1.38	0.49	1.87
5.1	Ocean Transport	1.22	0.00	1.22
5.2	Unloading and Inland Transport	0.00	0.29	0.29
5.3	Tax, Duty, and Insurance	0.16	0.20	0.36
6.	Indirect Field Expenses	0.10	0.30	0.40
7.	Engineering Services	2.30	0.48	2.78
7.1	General Contractor's Fee	1.50	0.25	1.75
7.2	Supervision and Service Man	0.80	0.23	1.03
8.	Project Management Services	1.80	0.72	2.52
8.1	Construction and Erection Advisor	1.50	0.47	1.97
8.2	Operation and Maintenance Advisor	0.30	0.25	0.55
9.	Base Project Cost, BPC (Without Taxes) -1983	14.97	18.68	33.65

Figure AV-1-3 PROJECT IMPLEMENTATION SCHEDULE

Project: Phosphate Rock Concentration Plant, PC-1
Product: Phosphate Rock, Bulk
Location: Sierra Grande, Rio Negro, Argentine
Feasibility Study: On the Establishment of a Phosphate Fertilizer Plant in the Argentine Republic



Notes: Milestone; ▲
(1) Project Approval, (2) Contract Award
(3) Foundation Works Start
(4) Foundation Works Completion
(5) Utility Supply Start, (6) Mechanical Completion
(7) Plant Acceptance and Commercial Production

Annex V-2

PROJECT DESCRIPTION FOR PHOSPHATE FERILIZER PLANT

PF - 1 ... GGPR

Granular Ground Phosphate Rock Production

PROJECT DESCRIPTION FOR GRANULAR GROUND PHOSPHATE ROCK PLANT
PF - 1 ... GGPR

Granular Ground Phosphate Rock Production

1. Project Outline

The proposed phosphate fertilizer plant project is to produce 347.4 TPD of granular ground phospate rock [0.0 - 33.87 (T-P_2O_5), 5.40 (F-P_2O_5)-3.00] by solid mixing granulation of phosphate rock with potassium chloride as granulation aid and as partially for fertilizer potash addition.

The raw material phosphate rock will be recovered from non-magnetic tails at the proposed phosphate rock concentration plant in Sierra Grande, Argentine.

Raw materials are phosphate rock, and potassium chloride (muriate of potash) of which requirement is minor and which will be procured locally despite it's origin is from oversears.

The final product is granular ground phosphate rock (GGPR) in bag, which is considered straight phosphate fertilizer with a minor amount of potash fertilizer addition. The fertilizer standards in Argentine designates the effectiveness of this type of direct application phosphate fertilizer should be evaluated by formic acid soluble phosphate.

The design capacity of the plant is 347.4 TPD of GGPR and annual production in 297 days in 103,178 TPY. The major facility in the plant is as follows:

Process Plant;

-Granular Ground Phosphate Rock	347.4 TPD

Utility Plant;

-Electric Power Receiving	2,000.0 kWh/h
-Natural Gas Receiving	0.5 MMSCFD
-Raw Water Treatment	200.0 TPD
-Steam Generation	0.3 TPH
-Waste Water Treatment	200.0 TPD

Storage and Material Handling Facility;

-Phosphate Rock	10,000 Ton
-Product	35,000 Ton
-Product Bagging	100 TPH

Auxiliary Facility;

-Administration Building	750 m^2
-Maintenance Shop and Storage	1,000
-Others	

Total area for the project site is 37,500 m^2 (150m x 250m).

2. Plant Description

2-1 Granular Ground Phosphate Rock Plant

(1) Introduction

Phosphate rock and granulation aid potassium chloride is mixed and granulated in solid mixing process to form homogenous granular product.

(2) Process Description

The raw material phosphate rock is directly mixed with potassium chloride at constant weight ratio in pug mill mixer. The particle size distribution of phoshate rock is small enough for the direct application, in the mixer a small amount of water is added for granulation conditioning.

The wet mixed materials are fed into a rotary drum granulator where steam is added for the homogenous and hard granulation. The granulated wet material is then dried in a rotary drum dryer where natural gas fired hot air is fed co-currently.

The dried granular material is screened and cooled in a rotary drum cooler, and sent to the bulk product storage and bagging plant.

Off-sized material of oversize is crushed and mixed with undersize, and returned to the mixer for further processing.

The specification of phosphate rock is shown in Table AV-2-1.

Table AV-2-1 ANALYSIS OF PHOSPHATE ROCK EXTRACTED FROM IRON ORE CONCENTRATION NON-MAGNETIC TAILS OF HIPASAM, SIERRA GRANDE, ARGENTINE

(1) CHEMICAL ANALYSIS

As Element	Weight Percent	As Oxide	Weight Percent	Equivalency for 100g Sample
P	15.56%	P_2O_5	35.65%	(-) 1.507
C (Carbonate)	0.09	CO_2	0.33	(-) 0.015
F	1.50	F	1.50	(-) 0.079
Cl	0.01	Cl	0.01	(-) 0.0005
OH	-	OH	(3.88)	(-) (0.2285)
S (Total)	-	S and Oxides	-	(-) -
S (Sulfide)	0.48	S	0.48	(-) 0.030
S (Sulfate)	-	SO_3	-	(-) -
Si	1.98	SiO_2	4.24	(-) 0.141
Fe (Total)	5.80	Fe Oxides	7.67	(+) 0.233
Fe (II)	4.36	FeO	(5.61)	(+) (0.156)
Fe (III)	1.44	Fe_2O_3	(2.06)	(+) (0.077)
Al	1.46	Al_2O_3	2.06	(+) 0.162
Mn	-	MnO	-	(+) -
Ca	31.66	CaO	44.30	(+) 1.580
Mg	0.22	MgO	0.36	(+) 0.018
Na	0.15	Na_2O	0.20	(+) 0.006
K	0.07	K_2O	0.08	(+) 0.002
Others	-	Others	-	-
Free Moisture	0.14	Free Moisture	0.14	-
Organics	-	Organics	-	-
Ignition Loss	1.68	Ignition Loss	1.68	
Total	65.95	Sub-total	102.58	(-) 2.001
		Adjustment for F	(-) 0.63	(+) 2.001
		Total	101.95	(+) 0.000

(2) PHYSICAL PROPERTY

Color: Gray

Size Distribution (Tyler Mesh and Millimeter)

(+) 400	Mesh	(0.0370 mm)	15.9%
(+) 468.4		(0.0316)	18.4
(+) 677.8		(0.0219)	36.1
(+) 993.3		(0.0149)	52.5
(+) 1,309.7		(0.0113)	64.5
(-) 1,309.7		(0.0113)	35.4
			100.0

Density	3.27
Bulk Density - Packed	1.67
Bulk Density - Loose	1.27
Angle of Reponse	43.0°
Free Moisture of Filter Cake, %	13.0
Specific Surface Area, cm^2/gr	2,770

(3) FERTILIZER PROPERTY

	Weight Percent	Solubility Percent
Total P_2O_5	35.65%	100.0%
Nitric Acid Soluble P_2O_5	35.60	99.9
Hydrocholoric Acid Soluble P_2O_5	35.11	98.5
Citric Acid Soluble P_2O_5	7.96	22.3
Formic Acid Soluble P_2O_5	5.69	16.0
Ammonium Citrate Soluble (AV) P_2O_5 (Neutral)	0.00	0.0
Water Soluble P_2O_5	0.00	0.0

Notes:
- Sample tails (Fe=27.53%, P_2O_5=7.08%) were taken on October 6, 1983 at HIPASAM and concentration test and analysis were made at NIKKO Consulting and Engineering Co. Ltd., Japan in January, 1984. Recovery of P_2O_5 is 55.5%. Fertilizer property was determined at Nissan Chemical Industries, Ltd., Japan in March, 1984.
- Ignition loss is measured by heating at 900°C for 0.5 hours.
- Free moisture is measured by heating at 105°C for 5.0 hours.
- (OH) is estimated to keep balanced equivalency.

(3) Product Specification

The plant is to produce 347.4 TPD of granular ground phosphate rock fertilizer in bulk under normal operating conditions.

The specification of the product is as follows:

Granular Ground Phosphate Rock	
Daily Production;	347.4 TPD
Analysis;	
-Total P_2O_5	33.87%
-Citric Acid Soluble P_2O_5	7.60
-Formic Acid Soluble P_2O_5	5.40
-Ammonium Citrate (Neutral) Soluble P_2O_5	0.00
-Water Soluble P_2O_5	0.00
-Water Souble K_2O	3.00
-Moisture	0.70
Conditions;	
-Temperature	40.0°C
-Pressure	1.0 ata
-Size Distribution	
(+) 4.0 mm	2.0 %
(-) 4.0, (+) 1.0	95.0
(-) 1.0	3.0
-Bulk Density	1.2
-Angle of Repose	35°
-Crushing Strength (2.0mm)	3.5 kg

(4) Raw Material, Utility, Chemicals and Catalysts Consumption

The consumption of raw material and utility for the production of granular ground phosphate rock under normal operation conditions is as follows:

	Production and Consumption		
	Unit Product	Hourly	Daily
Production;			
-Granular Ground Phosphate Rock, Bulk, Ton	1.000	14.475	347.4
Consumption;			
-Phosphate Rock (P_2O_5; 35.65%), Ton	0.959	13.888	333.3
-Potassium Chloride (W-K_2O; 60.00%), Ton	0.051	0.738	17.7
-Electric Power, kWh	42.500	615.19	14,764.5
-Water, Ton	0.160	2.32	55.6
-Steam, Ton	0.013	0.19	4.5
-Natural Gas, MMBTU-LHV	0.475	0.88	165.0

2-2 Utility Plant

The major utility plants required for the granular ground phosphate plant are designed to have following capability:

	Facility Capacity	Normal Demand
Electric Power Receiving, kWh/h	2,000.0	615.0
Natural Gas Receiving, MMSCFD	0.5	0.2
Raw Water Treatment, TPD	200.0	86.9
Steam Generation, TPH	1.0	0.2
Plant and Instrument Air, Nm^3/H	20.0	12.50
Waste Water Treatment, TPD	200.0	86.9

2-3 Storage and Material Handling Facility

The major facility for raw material, intermediates, and product receiving, storage, bagging and other material handlings are designed to have following capability:

	Facility Capacity	Normal Demand
Storage Facility;		
-Phosphate Rock, Ton	10,000	336.7 TPD
-Potassim Chloride	1,000	17.9
-Product, Bulk , Ton	35,000	347.4 TPD
Bagged, Ton	1,750	347.4 TPD
Bagging and Loading Facility;		
-Product, TPH	100	14.5