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THE CHROMITE PROJECT DEFINITION MISSION TO THE PHILIPPINES

FEBRUARY 1983

Prepared by Josiah Royce

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Introduction:

The Trade and Develoment Program (TDP) as part of its assigned task to broaden opportunities for U.S. private sector mining firms to participate in the development and diversification of foreign sources of supply of strategic and critical materials, is investigating potential alternate economic sources of chromium.

This report summarizes the findings of a team of earth scientists who visited the East-West Center's Resource Systems Institute in Hawaii, and mining institutions in Manila and mines in the Zambales District in the Philippines from February 19, until March 2, 1983. The team consisted of:

Josiah Royce; Coordinator of Mineral Activities, TDP Team Leader

Earl Herkenhoff; Extractive Metallurgist

David Jordt; Geologist/Geochemist

The Chromite Resource Situation:

The U.S. Bureau of Mines estimates for 1981 show the world mine production of chromite ore as 10,225,000 short tons, of which South Africa produced about 3.2 million, and Communist Bloc countries 3.7 million tons. The Philippines mined 490,000 and Zimbabwe accounted for about 580,000, while the United States, which consumes 16% of the world's production, has mined none domestically since before 1977.

The distribution of world chromite resources (some 36 billion tons) is even more uneven, with nearly 99% reportedly concentrated in southern Africa. As U.S. defense and energy programs become more extensive and sophisticated, resistance to high temperatures, corrosion, and abrasion is expected to increase the demand for chromium. (Each Pratt and Whitney F-100 turbofan engine used in our F-15 and F-16 fighter planes requires 1656 pounds of chromimum, for example.) This situation has motivated the U.S. Government to stockpile chromimum-bearing materials as tabulated below:

Stockpile Status - 11/30/81 (thousands of short tons)

MATERIAL	GOAL	TOTAL INVENTORY
Chromite:		
Metallurgical Grade	3200	1957
Chemical Grade	675	242
Refractory Grade	850	391
Chromium Ferroalloys	350	759
Chromium Metal	20	4

(In addition, the stockpile contained the following off-grade materials: 531,219 tons of metallurgical grade chromite and 20,762 tons of chromium ferroalloys.)

The Department of Commerce announced, on December 3, 1982, that the President had approved a program to upgrade chromium materials in the stockpile to help maintain domestic ferroalloy manufacturing capacity. The program plans to produce 519,000 short tons of high-carbon ferrochrome during the next ten years and stock it.

Since U.S. chromium resources, in the Stillwater complex in Montana and beach sands in Oregon, are considered subeconomic, the Trade and Development Program is investigating the possibility of developing new or enhanced sources of chromite in friendly countries outside the U.S., maximizing U.S. private sector participation in accordance with its mandate.

The Geology of Chromite:

Chromite, ($FeCr_2O_4$), the only mineral mined extensively for its chromimum content, is black, heavy, slightly magnetic, isometric in form, and has no distinct cleavage. It is found exclusively in mafic and ultra-mafic rocks, crystallizing early in peridotite and serpentinite. The derivatives and alteration products of these rocks, such as placers and laterites, also contain, in places, economic deposits from which chromium can be extracted.

Nearly all chromite mined today comes from two types of primary deposits:

a) Stratiform deposits are found in Precambrian land masses in thin layers in igneous intrusions like the Brushveld Complex in South Africa and the Great Dykes in Zimbabwe, both of which countries are major producers. In addition, there are occasional rumors of large undeveloped stratiform chromites in western Australia. Stratiform chromites, perhaps because of their large areal extent and ease of recognition, form the bulk of the known reserves.

b) Podiform chromites occur in irregularly shaped lenses averaging less than 1000 tons, but generally have a desirably high chrome-to-iron ratio. The largest podiform chromite deposit in the world is the 15 million ton plus Coto deposit(more accurately a swam of deposits) in the Zambales District of the Phlippines, which we visited. Podiform deposits are difficult to find, since, though chromite is very dense, magnetite and other minerals may obscure its gravity anomaly and its rather weak magnetic response.

Podiform deposits range up to 1 billion years old (Less than half of the age of the African stratabound chromites.) and usually occur in rare Alpine mafics which Dr. Charles Johnson of the East-West Center estimates may account for only 0.2% of the world's land surface area.

The south-west Pacific contains perhaps as much as one-fifth of the world's Alpine ultra-mafic rocks and thus is a good target area for those seeking podiform chromites which are often high grade, with high (desirable) chrome to iron ratio. In the south-west Pacific area, the Philippines are felt to have the largest known potential for further podiform chromite finds. Since large high-grade stratabound chromites are not well known outside the producing areas in Africa, the problems attached to finding podiform deposits must be overcome.

Secondary deposits contain vast tonnages but until the advent of Argon Oxygen Decarburization (AOD) allowed the use of low Cr/Fe ratio ores, the chromite in laterites was not widely mined. Residual chrome-bearing lateritic soil, overlying dunites, may contain more than 3.5% Cr_2O_3 and represent a future source of chromite ore in the southwest Pacific and particularly the Zambales area of Luzon. Laterites associated with nickel deposits are of lower grade, but may be mined when nickel prices rise. Alluvial deposits in the southwest Pacific are probably too low grade at present price levels. However, placer sand deposits below major ultramafic zones, similar to those on Palawan in the Philippines, tend to have higher chromite concentrations.

The key to increasing Philippine mineable chromite reserves output, therefore, be to find more podiform deposits in the ultramafics and/or to locate zones of chrome-rich laterite overlying dunite.

In Manila, meetings were held with the Director, Juanito C. Fernandez, and members of the staff of the Bureau of Mines and Geosciences of the Philippine Ministry of Natural Resources, and Attorney Delfin L. Gonzales, Executive Vice President of the Philippine Chamber of Mines. Attorney Gonzales invited Mr. Florante P. Escalante Assistant Vice President, (Development) of the Benguet Corporation, Mr. Eric L. Lee, Executive Vice President and Director, Malayan Wood Products Inc., Mr. David Cruz of New Frontier Mining Company, and Mr. Egon Berger, Vice President of Economic Research and Planning of Acoje Mining Co., Inc., to discuss Philippine chromite mining and its legal and regulatory environment with the team. In addition, Mr. Richard Smylie, Assistant Commercial Attache and Mrs. Cleo Alday Ledonio, Senior Commercial Specialist, counseled us on Philippine business procedures and assisted the team on logistics, travel, and administrative matters.

The Philippine Mining Law:

Any American firm, engaging in mining and/or mineral exploration in the Philippines must operate under provisions of the Presidential Decrees covering mining which are No. 463 and subsequent amendments in Nos. 1385, 1654, and 1677.

This report was not prepared with legal assistance and does not purport to be a study of Philippine mining laws in depth, but some provisions of the Decrees are set forth in Appendix I herewith, to assist U.S. firms in assessing the mining climate in the islands. (See Appendix I).

Philippine Chromite Mineral Activities:

Following the meetings in Manila, the team proceeded to the Zambales Range, south of Lingayen Gulf, on the island of Luzon, accompanied by Mr. Jose Caranceja of the Bureau of Mines and Geo-Sciences.

Our first stop was a custom chrome beneficiation plant (Solid Chrome, Inc.) near the coast. It was constructed from local materials and reconditioned machinery. With maximum ingenuity and minimum capital outlay, this operation treats a few tons of crude chrome ore daily when provided with feed by individual miners in the vicinity.

The second stop was the Masinloc Chromite Operation of the Benguet Corporation who mine the Coto and associated chromite orebodies. (Coto has long been considered the largest single chromite ore body in the world and has been in production since 1937.) See Figures 1 and 2

The chromite ore occurs in a faulted series of ultramafics with dunite, saxonite, and gabbro, heavily cut by diorite dikes. For more detailed information on the geology turn to Appendix II prepared by David Jordt, Geologist/Geochemist.

Table 1 below is from a paper by R.A. Besa, Vice President, Operations, and S.D. Dela Cruz, Group Manager, Geology Masinloc Chromite Operation, and tabulates reserves:

Ore Reserves, Masinloc Chromite Operation
Benguet Corporation (As of May, 1982)

Orebody	Estimated Reserve (DMT-ROM)	Average Grade Cr_2O_3	Average Grade SiO_2	Remarks
909	502,575	33.05	4.97	Open pit
Western	449,275	32.92	4.77	Underground
Lower Western	2,500,000	34.53	5.10	Underground
787	202,364	31.88	6.33	Open pit
1111	200,000	31.23	5.33	Underground
G-Layer/CLL	456,159	29,98	7.16	Open pit
Eastern	186,229	31.10	7.17	Underground
Hayden-Lenses	101,295	31.0	6.80	Open pit
587	167,729	29.44	8.01	Open pit
Murphy	11,609	32.07	6.98	Open pit
815/1124	430,912	28.46	8.00	Underground
Harding Lens	463,841	28.66	7.98	Underground
Sub-total	8,800,536			
Statelite Mines:				
Buntak	126,500	32.00	6.00	Open pit
Coral	145,500	31.57	6.48	Open pit
Total	9,072,536			
Baltap	19,500	33.00	7.81	Open pit
Coto Float Ore	13,028	31.58	3.28	Float Areas
Coto Main	31,077	30.93	8.07	Open pit
Grand Total	9,136,141			

These numerous, small ore bodies require operations in several areas by both open pit (about 70% of ore) and underground (about 30%) methods. In the open pit there are 22 power shovels (capacity varies from 1/2 to 2 1/2 cubic yards), 34 company-owned haulage trucks (12 to 35 tons capacity), 60 contractor-owned trucks of 12.5 ton capacity, 9 percussian drills for 2 3/4" holes, 15 bulldozers of assorted sizes, and nine compressors.

The underground mining is by cut-and-fill stoping with an accelerated development program designed to make available shortly increasing amounts of the low-silica ore encountered at depth by exploratory drilling. The mines employ 1745 people, of whom 628 work underground, 192 are in the open pit, 209 are in the ore processing plant, and 716 are in support operations.

The run-of-mine ore from both open pit and underground is cleaned and concentrated by washing, hand sorting, screening, and gravity concentration. For a more detailed treatment of the beneficiation plant at the Masinloc operation, see the report by Earl Herkenhoff attached as Appendix III.

The production goal for 1982, from a crude ore analysing approximately 12% Cr2 03, and based on the mining and milling methods just described, is set forth in Table 2 below:

Product	Size Spec.	Minimum Cr203	Maximum Si02	Tonnage(DMT)
MB-28	+5/16"-8"	28.00	8.00	27,600
Reg Lump	+5/16"-8"	31.00	6.50	8,850
Fine Lump	-5/16"+10M	31.00	6.50	14,100
Plus 10	-5/16"+10M	32.00	6.00	60,000
Minus 10	-10M + 65M	33.00	3.95*	84,000
Losil	-65M + 325M	34.00	2.00	15,150
Wemco Sand	-65M +100M	34.00	5.00	3,000
		Total	212,700 DMT	

*Note: Formerly 4.5%

In 1981, some 963,831 tons of crude ore were millled (73% from open pits) to produce 271,085 dry metric tons of refractory chrome ore, of which 216,438 were exported, 6,221 tons sold locally, and the rest stocked. This resulted in a 1981 profit to Benguet of 66 pesos per metric ton shipped as tabulated below:

HIGHLIGHTS	1981	1980	1979	1978	1977
Revenue per Tonne Milled	P167	P 184	P 128	P 126	P 138
Cost per Tonne excl. Taxes and Duties	P144	P 110	P 77	P 55	P 51
Taxes and Duties per Tonne	P 8	P 4	P 20	P 18	P 23
Ore Milled (000 dry tonnes)	964	1,083	1,282	1,302	1,142
Concentrate Produced (000 dry tonnes)	271	344	404	402	399
Average Mill Recovery	28%	32%	32%	31%	35%
Concentrate Shipped (000 dry tonnes)	223	283	301	377	385
Revenue per Tonne Shipped	P721	P 706	P 547	P 434	P 408
Benguet's Net Income per Tonne Shipped	P 66	P 28	P 9	P 23	P 22

The Benguet firm, whose stock is traded on the New York Stock Exchange, started mining gold in 1903, chromite in 1934, and copper in 1971. Benguet's net overall earnings in 1981 were $23,300,000 from an operating revenue of $243,000,000. A chromite expansion plan is ready if the market improves, and deeper ore gives promise of a lower silica content.

The team next visited the Acoje Mining Company Limited's mine of the same name. In 1981, this company produced 89,394 metric tons of concentrates from 392,816 tons milled and 398,145 tons mined. This underground property is changing over from top slicing to ascending cut-and-fill stoping. An aggressive diamond drilling program has enlarged the ore reserve to nearly 5 million tons and a small prospect, called Bunajan, 12 kilometers to the east of the Acoje mill, has been partially explored revealing nearly 84,000 tons of measured economic reserves and as much as 761,000 tons of indicated economic reserves. In addition the company has a metallurgical chromite property on Dinagat Island, Surigao del Norte, which is under exploration and may contain more than 4 million tons of metallurgical chromite ore. The company has reported a net loss for 1981 of 51,148,745 pesos.

Future Philippine Chrome Activities for U.S. Mining Firms with Appropriate Assistance from TDP:

Since nearly 10,000 square kilometers of ultramafic host rocks outcrop in the Islands, it is not unreasonable to place total indicated and inferred economic reserves at 100 million tons of ore running in the vicinity of 32% Cr203. Naturally considerable exploration will be required to confirm this. For more detail see Appendix II.

The following represent alternative interventions suggested to and by the team:

1. Formation of a joint venture with a Philippine company for expansion of an existing mining and/or processing operation. (We know of one Philippine mining firm seeking a U.S. partner, and will provide the name of their U.S. representative on request.)

2. Alliance with one or more Philippine firms to explore for podiform chromite, and/or chromite-bearing laterites, and/or chromite beach or river sand deposits. As indicated by Jordt, exploration should stress geochemical methods. (See Appendix II).

3. Establishment of a joint venture enterprise to build a ferrochrome plant in the Philippines, perhaps based on successful completion of the above exploration. (This should be located near a low-cost energy source.

4. Join with several Philippine mining operators to construct and operate a beneficiation plant to concentrate and agglomerate fine, disseminated (low-grade) chromites not now being mined. This plant might also mill ores of other companies on a custom basis.

5. Establish a factory to make refactory bricks in the Philippines.

6. This writer would draw attention to Jordt's mention, on page 16 of Appendix II, of a methane gas seep in the Zambales ultramafics.

One possibility for the emplacement of the Zambales ultramafics is that a fragment of sea floor was pushed up (obducted) onto later, perhaps sedimentary, crustal formations. If this is true, and if the sediments contained hydrocarbons, it is possible that this methane gas seep indicates natural gas etc. trapped much like the hydrocarbons beneath the overlying rocks of the Overthrust Zone in the western United States.

This area merits further study.

Conclusions:

The chrome activities above offer a choice of interventions for U.S. mining firms desiring to enter or broaden the U.S. chromium production base by a Philippine joint venture operation. It is felt that, one or more of the alternatives may appeal to a U.S. firm depending on its market and its available financial and technological resources.

APPENDIX I.: SUMMARY OF PHILIPPINE MINING REGULATIONS

1. All mineral deposits are the property of the Government of the Philippines. Use of the private lands for residence, agriculture, or logging, does not convey ownership of mineral or mining rights.

2. The surface owners cannot prevent qualified persons from exploring for minerals.

3. No prospecting or mining is permitted in "Mineral Reservations", Military, or other Government reservations, unless authorized by the Governent agencies concerned.

4. A mining claim, to be registered, must be 81 hectares (about 200 acres) in area, more or less, and conform to 1/2 minute meridional boundaries.

5. The declaration of location of a mining claim is filed with the Mining Regional Officer concerned on a prescribed form.

6. Upon payment of prescribed fees the mining claim declaration will be filed and registered by the Mining Recorder concerned. The Director of the Bureau of Mines will keep a register in which dates, location and other pertinent claim data will be permanently recorded. Once recorded, the claim owner has right of entry to develop his claim.

7. The Director may charge reasonable filing and service fees. (Note: As charges and fees vary and the dollar vs. peso rate also varies we omit cost numbers. They appear moderate.)

8. A claim owner is required to do annual assessment work on his claims as prescribed. Work on one of a contiguous group of claims may be applied to hold others. Proof of work will be submitted to the Mines Regional Officer within 60 days from the end of the year for which the work is to be applied.

9. Within one year of registering a mining claim, the claim owner must apply to the Director for an official survey of the claim, which will be done at an established rate by a licensed geodetic engineer on the authority of the Director. Such survey will conform to government regulations, leave standard monuments, and must be finished and filed with the Director within one year.

10. Pending a formal lease agreement, the claimant may apply to the Regional Officer for a Temporary Mines Permit, and a temporary permit may be issued by the Director upon compliance with obligations due on the mining claims and posting of a surety bond in an amount approved by the Director. This temporary permit is valid for one year and can be renewed for a year more.

11. Within two years from the recording date the miner must apply to the Director for a formal mining lease. Failure to do so constitutes abandonment of the claims.

12. The application must be accompanied by a standard fee and at least the following must be included:

(a) A report by a licensed mining engineer or licensed geologist testifying that the claim is mineralized.

(b) Proof of compliance with annual work obligations. (If report is filed by an agent, copy of his power of attorney must be attached.)

(c) If land is covered by concession or right other than mining, written notice to the other permittee, or the requirements of Presidential Decree No. 512 must be complied with.

(d) The planned work plan proposed for the mining claim.

(e) Proof that the miner has both the technical competence and sufficient financial resources to develop the claim.

(f) Any other documents prescribed by the Regulations (Section 6 of P.D. No. 1677).

13. A single application may be made for contiguous claims, providing that the total area does not exceed the limit permitted to one concern.

14. All applications will be in prescribed form, under oath, and must give civil status and place of birth.

15. The claim owner shall, upon filing for a mining lease, undertake exploration, development, and/or mining activities in accordance with an approved five-year plan. Within the five years, actual commercial production must begin. Failure to do so will constitute abandonment of the claim(s). During the five years the claim owner shall submit, at the beginning of each new year, a report for the Director's approval on an annual work program describing in detail the work to be done in the coming year. Any deviations require the Director's approval.

16. If the Director finds the application in order, he shall have the application published once a week for two consecutive weeks in Manila and the province in which the mine is located. The application will be placed, by the Director, on the Bulletin Board of the Bureau of Mines for two consecutive weeks, and he shall order the applicant to post the notice and the approved mining plan on the bulletin boards of the municipality and the mines regional office in which the claims are located, and require an affidavit that they were posted.

17. If no protest is pending at publication, and no new protest is made within 15 days of publication, no adverse claims made thereafter shall be heard.

18. After verification of the mineral content of the claims and their location on the ground by the Director, the Minister shall approve and issue the corresponding mining lease contract for a period not exceeding 25 years, renewable, on expiration, for 25 additional years. After the expiration of the renewal, the operation of the mine may be undertaken by the Government through one of its agencies or a qualified contractor.

The contract for operating the mine shall be awarded to the highest bidder, but the lessee will have the right to equal the highest bid, upon reimbursement of all reasonable expenses of the highest bidder.

19. An individual may claim up to 500 hectares in any province and 1000 hectares in the entire Philippines.

20. Mining partnerships or Corporations may have 5000 hectares in one province or claim 10,000 hectares in the Philippines.

21. Claims can be mined for the claim-holders by agents under a service contract but the 60% Philippino, 40 percent foreign ownership and profit distribution limitation must not be exceeded.

22. Philipinos are to be given preference for employment in all phases of the mining operations for which they are qualified, and where foreign technologists and executives are employed, an effective program of training understudies is required.

23. If improvements have been made on the claims, such improvements must be removed within one year following abandonment, termination or cancellation of the lease contract.

24. No province, city, or municipal district may collect taxes of any kind on mines, mining claims, minerals, mineral products, or on any operations, process, or activity connected therewith. Only the federal government may tax mines.

25 .Occupation fees, rentals, royalties, and tax notes on mining claims and minerals extracted therefrom must be paid by the claimowner as specified in the National Internal Revenue Code. Failure to do so for two consecutive years cancels the claims.

26. Machinery, equipment, tools, beneficiation plants, materials, explosives, spare parts and chemicals, transportation and communications equipment for new mines, and for old mines resuming production, are exempt from customs duties, and all taxes except income tax, when duly certified by the Minister on recommendations of the Director, for a period of five years.

27. All mining claims, improvements thereon, and minerals extracted therefrom, are likewise exempt from all taxes except income taxes for a like period.

28. Within 30 days of payment of rentals and royalties on a mining lease the lessee must submit to the Director copies of receipt of payment, lease number, corporate name, and other pertinent particulars. Failure to provide this information is counted as nonpayment.

29. Subject to the rules and regulations of the Bureau of Forest Development, the miner may cut necessary trees within his claims. If a previous timber concession covers the claims, the Director shall determine what timber must be cut. If no agreement can be reached between the claimowner and the timber concessionaire, the matter shall be submitted to the Minister, whose decision shall be final.

30. However, a claimowner granted a timber cutting right shall be obligated to perform reforestation work on the claims in accordance with regulations of the Bureau of Forest Development.

31. A claimowner shall have water rights for the necessary development of his claims upon Application with the Director of the Bueau of Public Works. Provided, that prior exisiting water rights shall not be impaired, and provided further, that the Government reserves the right to assure reasonable distribution of water and prevent monopoly.

32. Easement Rights: Where claims are so located that, for purposes of more convenient development or exploitation by the claimowner, it is necessary to construct, on land occupied or leased by others, roads, railroads, power lines, waste dumps, tramways, port facilities, etc. the claimowner, upon payment of just compensation, shall be entitled to enter and occupy the needed land.

33. When the claimowner or occupant of the private lands mentioned above refuses to grant access to the claimowner, the claimowner may presecute under the Rules of Court in the First Instance of the province where the mining claims are located. In determining just compensation due the occupant of the land, the court shall appoint at least one duly qualified mining engineer or geologist, to be recommended by the Director, as one of the commissioners.

34. Lessees must give preference to Philippine citizens at all levels of employment insofar as they are qualified to perform the work without hazard to the operation. The claimowner is obligated to maintain effective programs of training and advancement, commensurate with the demonstrated abilities of Philippine citizens to perform the various operations involved. The lessee may, however, use employees of his own choosing, under provisions of the Commonwealth Act Numbered Six Hundred Thirteen (Amended), for technical and specialized work or work requiring long experience, with the approval of the Director. This employment cannot last more than 5 years. No foreigners can be employed as mine manager, vice president for operations or the equivalent, in charge of mining, quarrying or drilling, without passing the appropriate government licensing examination. In special cases the Director can waive this examination for a period of up to one year.

35. No person under 16 years old may be employed in any phase of mining, and no person under 18 may be employed underground.

36. Only the Director or his duly appointed representative, in a reasonable manner, may inspect the work day or night, for compliance with exisiting regulations concerning safety and anti-pollution practices.

37. Conservation Measures: A lessee should include in his annual work plan to be submitted to the Bureau of Mines and Geo-Sciences, for the Director's approval, projects of research and development amounting to not less than 10% of the annual work obligations. This work will be evidenced by a technical report on optimum methods for arranging exploration and mining to prevent waste, pollution and damage to streams, surface or underground water supply, and other minerals. The lessee is required to take necessary steps to develop any potential industry, other than mining, to provide for people residing in the area when the mine is worked out or unprofitable.

38. At the close of operations the leased areas must be placed in a condition suitable for habitation or agriculture.

39. In connection with the work program a report shall be prepared by the lessee covering at least the following:

"Compiliation of Mining Rules and Regulations"

(a) Mining methods taking into consideration recovery, economy and safety;

(b) Milling and metallurgical processing taking into consideration optimum recovery;

(c) Waste disposal system;

(d) Provision for growth and development of any industry suitable for the area other than mining;

(e) Surface restoration and/or improvement of the mining area;

(f) Study of environmental impact and the effect of mining activities on the ecology of the area during and after operations; and

(g) List of all mining and milling machinery and equipment to be used together with their specifications, performance, and efficiency.

40. No temporary permit or lease shall be issued to an applicant or operator for extracting magnetite sand along beaches of the seas and lakes, and areas adjoining, including lands devoted to residential, agricultural, or reforestation purposes, unless within zones designated, by the Department of Natural Resources in consultation with the Department of Tourism, and the Department of Local Governments and Community Development, as open to mining, and supported by a project study for mining and restoration of the mined out areas previously approved by the Director. No applicant will be permitted to mine magnetic sand unless he shall have proven his financial capability and technical competence to arrange restoration of the land.

41. It is prohibited to extract magnetite sand from beaches with recreational and/or tourist potential, at places inland located less than 200 meters from high tide water level, 50 meters from the centerline of municipal or national roads, property boundaries of public and private structures, and offshore areas less than 100 meters from the beach at low tide.

Fill material shall in no case wholly come from adjoining inland areas, but rather from selected spots not less than 100 meters from the beach as approved by the Bureau of Mines and Geosciences. After filling the pits with sand they shall be covered by sufficient soil to sustain agriculture at previous ground level.

In cases where existing agreements with the landowner require that the mined out pit shall be a water hole for irrigation or fish pond purposes, a certificate of suitability for such purpose will be secured, by the landowner or the operator, from the National Irrigation Administration, or the Bureau of Fisheries and Aquatic Resources as appropriate.

42. As guarantee that this shall be duly carried out, a surety bond of not less than 20,000 pesos for each mining pit of one hectare or less shall be posted in favor of the Bureau of Mines and Geo-Sciences. Failure of the operator to restore the mined out area within 60 days of completing the mining will result in confiscation of the surety bond and cancellation of the lease.

43. Environmental Protection in Mining Areas

a) Operators are required, within 90 days from effect of the regulations, to submit a long-term plan covering the period of the lease for the protection and enhancement of the environment.

b) For implementation of the long term plan, within 60 days of the beginning of each calendar year, a work program will be submitted to the Director for approval. The program shall include but not be limited to: exploration, development, exploitation, rehabilitation, regeneration, revegetation and reforestation of mineralized areas, slope stablization, aqua-culture, watershed development and water conservation; and socio-economic development.

44. In preparation of long term plans and work programs the guidelines below will be used:

a) Surface Mining:

1. Operators will stock-pile and save surface soil for re-soiling of slopes, dumps, etc.

2. Waste-dumps will be located away from major drainage systems.

3. Control measures will be used to prevent spilling, slides and/or washing away of waste materials.

4. Mine dumps, and tailings-covered areas will be prepared for a useful purpose before abandonment. Slopes and road cuts will be stabilized by planting vines, legumes, and shrubs.

5. Completely mined-out areas will be rehabilitated by the miner before abandonment for possible development.

6. In cases where improvements for agriculture, industrial, commercial, or human settlement are not technically feasible, completely mined-out areas shall be revegetated pursuant to the approved plan submitted. Apropriate Government agencies can be called upon for advice.

7.(a) To assist in implementing the above all mine operators shall establish their own vegetable and forest nurseries of at least 500 square meters to raise seedlings.

(b) Underground Mining:

1. All underground openings that are abandoned shall be filled or developed to prevent subsidence. For this purpose, a plan shall be submitted to the Director for approval.

2. In cases of surface disturbances within mining claims attributable to underground mining operations, the mining operator shall immediately take remedial measures to prevent further damages. If affected areas are inhabited, the residents thereof shall be relocated by the operator.

3. The above activities shall be subject to inspection and evaluation.

(c) Mill Waste and Tailings Disposal and Water Conservation

1. All mine/quarry operators are prohibited from directly or indirectly disposing of tailings or mill waste into natural drainage systems including rivers and tributaries.

2. Impounding of mill tailings shall be far from water shed areas and free from spillage, slides and/or washing-away of tailings by surface run-off during heavy rains into drainage systems, creeks or rivers. Flushing of tailings is likewise prohibited.

3. All mine tailings-covered areas, if found not suitable for agricultural, industrial or commercial use, must first be resoiled, cover-cropped, or reforested.

4. Mill effluents shall be treated so that obnoxious odor and poisonous chemicals are removed before disposal.

5. Mining companies shall, at all times, conserve water by recycling, developing and maintaining watershed areas, by reforestation and afforestation, and by constructing water reservoirs for domestic, industrial, or aqua-culture uses.

The above represent the major regulations applying to mining, but numerous others involving definitions, cancellation of leases, formation of an environmental unit, minimum work obligations etc. merit the close scrutiny of any prospective U.S. mining investor interested in the Philippines. It is, perhaps, significant that an Austrian firm is increasing its participation in Philippine mining at this time. Voest-Alpine is apparently not intimidated by Philippine mineral regulations.

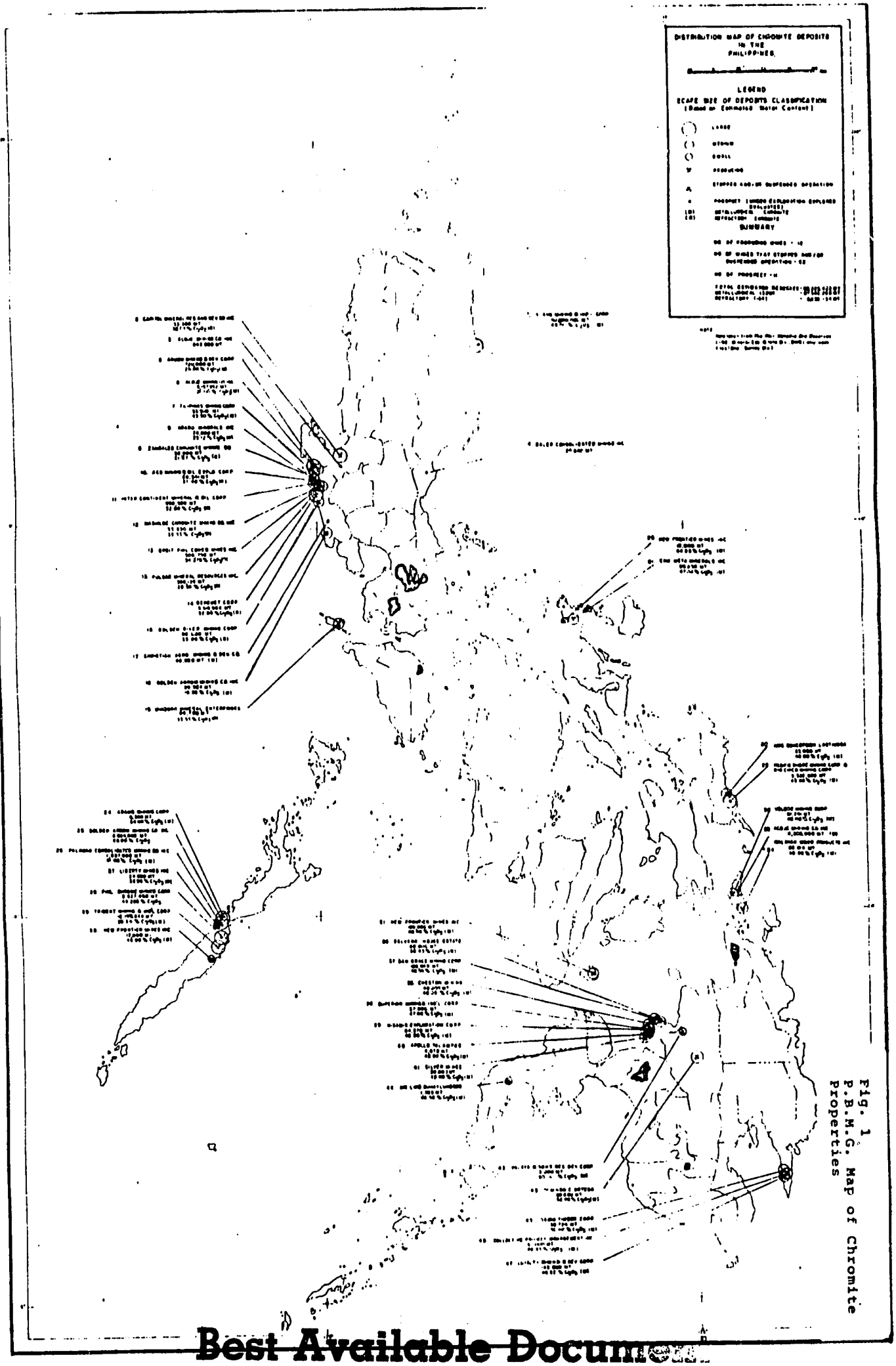
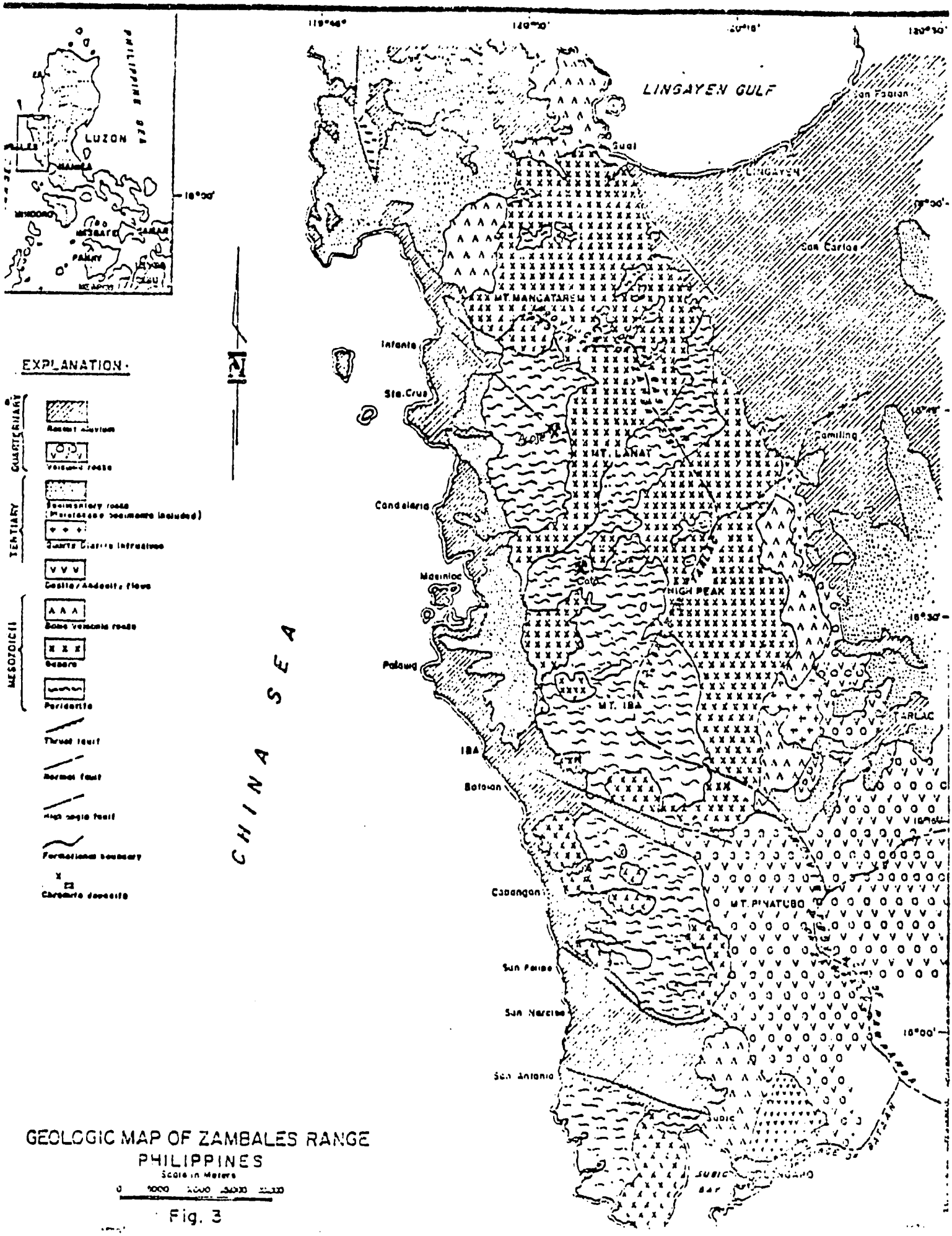


Fig. 1
P.B.M.G. Map of Chromite Properties

Best Available Document



GEOLOGIC MAP OF ZAMBALES RANGE
PHILIPPINES
Scale in Meters
0 1000 2000 3000 4000

Fig. 3

PRELIMINARY APPRAISAL
OF CHROMITE EXPLORATION POTENTIAL
IN THE PHILIPPINES

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PRELIMINARY APPRAISAL OF CHROMITE EXPLORATION POTENTIAL IN THE PHILIPPINES

David K. Jordt
Geologist

INTRODUCTION

The writer was engaged by U.S. Trade and Development Program to 1) assess the geology and tectonics of the Philippines for the presence of underdeveloped chromite deposits, 2) determine the most efficient means of exploring for those deposits, and 3) examine the records of any mining projects presented to the contractor to determine which if any merit further development.

Pursuant to the above, the writer spent four days at East-West Center, Resource Systems Institute, Honolulu, Hawaii, for literature and data review and consultation with Dr. Charles Johnson (Feb 14 - 19), then nine days in the Philippines (Feb 21 - Mar 2), during which officials of the R.P. Bureau of Mines and Geo-Sciences, Chamber of Mines, private mining industry personnel, and officials of the Asian Development Bank were conferred with. A two day visit was made to two major chrome deposits, Coto and Acoje, in the Zambales Range, 150 Km northwest of Manila.

CONCLUSION

Given satisfactory world markets, chromite exploration in the Philippines appears to be a good risk. Chromite abundance in the Philippine ultramafics suggest the area is an anomalous Cr-province.

There are over 10,500 Sq Km of ultramafic Chromite hostrock in the islands, but 3114 Sq Km of it closest to Manila has produced 98% of the ore. On an equal tonnage per area basis, the unmined chromite resource of the Philippines appears to be minimally 165,000,000 tons @ 32% Cr_2O_3, not including placers, soils, and laterites, which are only beginning to be appraised. Estimates of 2400M T of laterite chromite reserves have been made. Some of this would be Ni Co Pt bearing.

There has never been a comprehensive geochemical survey of the Philippine ultramafic environment.

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CHROMIUM: GENERAL BACKGROUND

There are at least 47 minerals in which chromium is a major constituent. While some of these may in the remote future constitute a low-grade chromium resource (e.g. fuchsite in some metamorphics, or tarapacaite (which the writer has seen in apparent carnotite mode in neogene sandstones in Iran), at present only chromite occurs in sufficient grade and abundance to be economically exploitable (Lipin, 1992).

Two fundamentally different types of chromite are mined: 1) metallurgical and chemical chromite for the contained chromium metal, and 2) refractory chromite, which is used like a nonmetallic for refractory fire brick. The standards, handling, and economics of these two are rather independent of each other. The Philippines contains both types.

Chromite: (Fe,Mg)(Cr,Al,Fe)2O4.
Theoretical maximum Cr2O3 content = 68% (for (FeCr)2O4).
Chromite concentrates usually range 32 - 55% Cr2O3.
For quick estimation one may consider Philippine pure metallurgical chromite at 50% Cr2O3, pure refractory chromite at about 40% Cr2O3.

Chromite ore host is ultramafic rock -- peridotite or serpentinite -- specifically the high magnesian forsterite-dunite members of ultramafic cumulate assemblages. There are upwards of 300,000 Sq Km of ultramafic rock exposed on the surface of the earth (Johnson, Brady, 1982). The SW Pacific contains about 60,000 Sq Km of this, the Philippines over 10,000 Sq Km.

Two fundamental types of ultramafic occurrence are recognized: 1) Stratiform ultramafics, being relatively undisturbed layered magmatic injections within continental rocks, and 2) Alpine, or ophiolitic ultramafics, which are the tectonized residuals of upper mantle rock brought to the surface by subcrustal convection at spreading centers and thence conveyed to a subduction zone at a continental margin where debated processes cause them to be obducted over, injected into, or otherwise retained by, the upper tectonic plate, wherein they are ultimately exposed by erosion. Philippine ultramafics are of the Alpine type.

Stratiform ultramafics yield "stratiform" chromite deposits which, perhaps because their uniformity facilitates reserve estimation, currently dominate world chromite reserves and production. At the moment somewhere between 88 and 99% of world chromite reserves are tallied in the Bushveldt Complex of South Africa and the Great Dyke of Zimbabwe, both stratiforms.

Alpine-type ultramafics yield "podiform" chromite deposits, in allusion to their shape. Chromite pods range in size from isolated "carnonballs" disseminated (sometimes minably) within peridotite ores, to individual pods in the order of 5,000,000

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lens. Unlike stratiforms, podiform chromites are unpredictable in size, shape, and occurrence. Their distribution is considered in a broad sense to be random, both laterally and vertically, within ultramafic terranes (Thayer & Lipin, 1978)

Podiform ore bodies are usually sharply defined. Mining is rarely controlled by an "assay wall" but rather by the physical edge of the ore body, which brings ore grade (25 to 100% chromite) up against unminable background. Intermediate grade disseminations are rare (Lipin, 1982).

At the current level of research, podiform chromites are usually undetectible unless they outcrop.

PHILIPPINE CHROMITE MINING STATUS

The history of chromite in the Philippines began with its discovery in the Zambales in 1927. Mining began in 1935 and by 1981 total production had reached 3,964,413 DMT (@ approximately 48% Cr_2O_3) metallurgical, and 14,134,322 DMT (@ approx. 34% Cr_2O_3) refractory chromite. For the past 30 years (1952 - 81) production has averaged:

metallurgical, 107,747 (+/- 32,171) TPY
refractory, 420,813 (+/- 95,115) TPY

Until recently, about 94% of the metallurgical chromite was produced by Acoje Mine, and 99% of the refractory by Benguet's Masinloc Mine, the world's largest podiform chromite deposit. Both of these deposits are located in the Zambales ultramafic complex on Luzon Island, 150 Km NW of Manila.

The Philippine Bureau of Mines and Geo-Sciences (PBMG) recognizes 47 chromite reserve properties in 14 districts scattered widely about the Philippines (Fig. 1, Appendix A). Twelve of these are operating. Bacuta (1979) cites 125 prospects and mines in 13 provinces or islands.

CHROMITE EXPLORATION POTENTIAL

General.

The whole chromite potential of the Philippines at this time is defined by podiform chromite occurrences within ultramafic rocks of the Alpine type (Thayer, 1979) or secondary chromite concentrations in laterites or alluviums (soil, sands, gravels, beaches).

Total exposed ultramafic area in the Philippines is in excess of 10,000 Sq Km. Johnson's team at East-West Center measured it at 12,500 Sq Km using 1:1M scale geological maps. George Bacuta, geologist with PBMG, figured the area at 11,500 Sq Km.(1). The writer, using planimeter and graphical methods on the set of 55 PBMG 1:250K scale provisional geological maps, measured 10,562 Sq Km.

At least 279 ultramafic bodies are mapped. These range in size from isolated 0.04 Sq Km blebs exposed along fault zones, to the 2700 Sq Km central Zambales massif.

Seventy-one of the mapped ultramafics exceed 10 Sq Km in area and total 9896 Sq Km. Nearly all of these occur within 12 groupings which the writer believes would be logistically favorable for exploration. These exploration areas are superimposed on the structural interpretation map of Fig. 2. Table 1 summarizes the ultramafic occurrences in these areas.

Exploration potential appears to be high. There has never been a comprehensive geochemical survey of the Philippine ultramafic areas (Dela Cruz, Fernandez, Obial, pers. comm).

Philippine Podiform Chromite Resource Predictions.

One of the more engaging pursuits in Philippine mining geology is the estimation of undiscovered chromite reserves. The problem is interesting because podiform chromite characteristically abhors discovery. Geophysically it is practically inert. Geologically and geochemically, at least by procedures used so far, podiform chromites are undetectible unless outcropping.

The PBMG estimates the reserves of its 47 listed deposits (Appendix A) at 96,223,412 tons (or 102,712,879 @ 39.1% using updated Colo and Acoje reserves). The USBM carries a Philippine "reserve base" judgementally at 3,300,000 T (Mineral Commodity Summaries, 1983). In 1978, a concensus of leading Philippine geologists estimated "predicted reserves" at 121,500,000 T.

TABLE 1

12 LOGISTICALLY FAVORABLE CHROMITE EXPLORATION AREAS
(See Map, Fig. 2)

Area No.	Region	No. UM bodies	Area (SqKm)
1	Zambales, Luzon	4	3114
2	Palawan	11	2016
3	NE Mindanao (Surigao), Dinagat Is, S. Leyte	58	1418
4	Mindoro-Sibuyan Islands	49	697
5	Sierra Madre, Luzon	7	658
6	West Mindanao	21	501
7	Samar - NE Leyte	19	431
~~8~~	~~Pujada Peninsula, S. Mind.~~	~~4~~	~~428~~
9	Tawi Tawi Island	4	385
10	North-Central Mindanao	32	369
11	S. Luzon, E. of 122-degrees	29	315
12	Panay, Western	24	138
	TOTAL EFFECTIVE TARGETS	262	10,471 Sq Km
	Remaining occurrences, generally isolated,	17	91
	TOTAL PHILIPPINE UM's	279	10,562 Sq Km
	Targets > 10 Sq Km	71	9,896 Sq Km

The writer has made an independent estimate of chromite reserves based on the following rationales:

chromite distribution being random, and ultramafic bodies being, in aggregate, more or less uniform, it can be assumed that, given no breakthroughs in exploration technology, chromite reserves in the entire Philippines should be at least proportional to the density of chromite abundance in the best-prospected area. That area is, without a doubt, the huge Zambales Range ultramafic complex of Luzon.

Though containing only 29.5% of the total ultramafics in the Philippines, this area of about 3114 Sq Km has produced over 98% of the refractory and 91.5% of the metallurgical chromite. Rather than demonstrating the streakiness of chromite distribution, it is felt that this more likely represents a kind of "self-fulfilling production." The Zambales block is located less than 5 hours drive from the Philippines' main population center and logistic support base, Manila. The area is adjacent to an ocean, and surrounded by paved highways and national power grid. Subic Bay Naval Base is located on one side of it, and Clark Air Base on the other. That the earliest significant chromite reserves were blocked out here is scarcely surprizing. These discoveries plus the logistic advantages have doubtless fueled the on-going proliferation of discoveries. The Coto "Mine" has actually consisted of a swarm of 17 ore bodies developed over a distance of about 7 Km, with more prospective occurrences distributed out to ~~over 20 Km.~~ The Coto's reserves ~~were~~ figured at 10,000,000 T ~~in~~ 1936 and remain about that today, 14,000,000 tons later.

To calculate overall Philippine reserves at exploration level equal to that of the Zambales, the following expression was used:

Reserves = (Philippine UM area / Zambales UM area)
times
(Zambales production + reserves)
minus
(Philippine total production to date)

There are 14 chromite properties listed by BDMG for the Zambales. Bacuta (1) cites 62. Total chromite ore represented by the Zambales block is:

Production:	Refractory (1936-82)	14,097,103 T @ 34% Cr2O3
	Metallurgical (1935-81)	3,638,525 T @ 48% Cr2O3
Reserves:	Refractory (Jan 83)	10,781,993 T @ 31.6% Cr2O3
	Metallurgical (Dec 82)	8,023,148 T @ 23.2% Cr2O3
	ZAMBALES TOTAL	36,540,769 T @ 32.3% Cr2O3

Thus: (19562 Sqkm / 1114 Sqkm)

x 36,530,767 T

- 14,205,322 T (Historic Refractory Production)
- 3,964,413 T (Historic Metallurgical Production)

= 105,646,005 T @ 32 % Cr_2O_3

(Predicted podiform chromite reserves of Philippines at current exploration level of Zambales)

Risk factor in this number is the assumption that Zambales is a good datum; the Coto chromite swarm does seem anomalous. On the other hand, there are conservative influences. Reportedly there has never been a systematic geochemical survey of the Zambales ultramafics -- or any other Philippine ultramafic, for that matter. Moreover, as can be seen in the geological map, Fig. 3, the chromite hostrock of the Zambales complex - peridotite - is over 50% covered by gabbro. Given an effective indirect geochemical sensing method, much of this might be prospectable, as would also be the extensive, apparently-barren peridotite areas where chromite pods undoubtedly exist but are unexposed. There is already evidence that chromite might be geochemically detectable under the gabbro; chromite veinlets within gabbro are occasionally seen in the vicinity of podiform orebodies, implying that, while chromite may differentiate before gabbro, it remains, at least in part, mobile throughout the period of gabbro consolidation. In these cases it is apparently always accompanied by its peculiar magnesium geochemical envelope, high-forsterite dunite.

It is worth noting that Zambales chromite tonnage per unit area is 11,771 Tons/Sqkm, and is bound to rise. This is rather higher than the world average, calculated by Johnson (1982) as 4500 T/Sqkm, excluding Southern Africa and SW Pacific. The Philippines may well be an extraordinary chromite province and eminently prospectable for that reason. At least for those parts of the free world lying outside the easily-disruptible areas (Finland, Turkey, Southern Africa), the Philippines already account for 17% of total chromite production.

Laterite and Sediment Reserve Potential.

Eluvial, alluvial, and laterite chromite deposits are recognized. Since they probably owe largely to original disseminated rock chromite contents rather than broken down minable podiforms, any reserves calculated for this category would not be at the expense of podiform reserves predicted above.

Palawan has an estimated 10M T @ 5.5% Cr_2O_3 sand, 400M T @ 0.7% Cr_2O_3 soil (Johnson, 1987): the Philchrome deposit, now producing. This would add 10,469,000 T of 32% to the estimated podiform reserves. PBMG carries this deposit as 2,627,498 T @ 44.2865% Cr_2O_3.

The Kinalablaban R. mouth in Surigao del Norte, NE Mindanao, contains undisclosed reserves of chromite-magnetite-bearing beach sands with approximately 1.67% Cr_2O_3 (calculated from Ref.12).

Relevant to this, the writer noted that there are about 24,000 meters of consistent 150 meter-wide gravel riverbed draining the Coto Mine area. At average 5m depth this amounts to 18,000,000 cubic meters of alluvium or 36,000,000 T at some grade Cr_2O_3. It might be worth appraising, along with some of the other rivers draining the Zambales Range.

Ni-Pt-Cu-bearing laterite-chromite reserves are now being blocked out adjacent to the Acoje Mine. An early reserve estimate by Acoje (May, 1980) indicated a laterite cap averaging 3.5m depth, max 5m:

3,600,000 T @ 6.8% Cr_2O_3 (at 4% cutoff)
Ni ranging 0.2 to 0.4%
Pt-Pd-Os ranging 0.02 to 0.04 Oz/T,
(with 1/3 Oz Pt assay reported)

The impression was gotten that Pt-metals potential might well be effectively pursued here. That would apply to the other Philippine ultramafics as well.

At Acoje, laterite Cr_2O_3 grade is a reflection of underlying bedrock grade. Chromite values are highest near the surface. Cu is correlated with Ni content so well that it is analyzed as an Ni reserve indicator.

Chromite-bearing laterite, as a category of deposit, would be well worth appraising. An indication of this potential might be found in estimates of Philippine laterite Ni reserves, which derive from the chromite hostrock.

Laterite-Ni Deposits as a Guide to Laterite-Cr Potential.

PBMS lists 27 laterite-Ni deposits in the Philippines. These total:

175M T @ 1.172% Ni; contents of Cr and Pt not reported.

USBM, Denver, reported in mid-82 a "demonstrated" in-situ sand/soil tonnage of:

178.5M T @ 2% Cr_2O_3,

which is equivalent to:

11,156,000 T @ 32% Cr_2O_3 (to keep it in the same magnitude as resource estimations herein)

East-West Center gives a general estimate of Cr-laterite potential based on a rough estimate of Ni-laterites:

2400M T @ 2.5% Cr_2O_3,

which is equivalent to:

187,000,000 T @ 32% Cr_2O_3.

The vulnerable number here is the 2.5% Cr_2O_3 grade.

Two laterite-Ni properties are now producing: Rio Tuba, in South Palawan, with reserves of:

32,865,000 T @ 2.07% Ni, direct shipping ore, (304,930T of 2.3% shipped in 1981),

and Marinduque Mining's Nonoc Island Ni deposit, with reserves of:

203.5M T @ 1.23% Ni and 0.1% Co. (23,928T of Ni metal produced, 1981)

The exploration potential for Cr-laterite and/or Cr + Ni,Co,Pt-laterite occurrences in the Philippines seems good in view of the prevailing paucity of geochemical coverage of ultramafic areas. Any geochem survey designed for podiform exploration would be bound to indicate also any areas in which potentially-economic soils/laterites are high probability.

CHROMITE EXPLORATION CONSIDERATIONS.

It is apparent that a large part of the disparity between world wide stratiform and podiform chromite reserve estimates owes to the fact that there has yet to be developed an adequate exploration method for the detection of blind podiform orebodies. It is equally apparent that the development of such a method would probably increase podiform reserves more radically than would the rigorous, systematic application of traditional prospecting techniques. Given an effective sensing method, the Alpine ultramafic environment would suddenly be thrown open to discovery almost as if it had never been prospected in the first place. It would seem therefore that there is more chromite reserve-growth potential to be found in the laboratory than in the field at this point in time.

A discussion of possible exploration approaches and their problems follows.

Gravity.

Although certain orebodies in Cuba, and the near-surface 787 orebody at Coto, were discovered with a gravimeter, in general the specific gravity contrast between chromitite and hostrock, the relative small size of chromite bodies, and the specific gravity variance and structural complexity of the hostrock mitigate against effective use of this method. Chromite varies from 4.1 to 4.9 specific gravity, ultramafics from 2.4 to over 3.2. Assuming fixed S.G.'s of 4.6 for chromite and 2.9 for ultramafics, we get the following hypothetical chromitite specific gravities through the expectable range of massive orebody chromite grades:

0 % Cr_2O_3	2.9 S.G.
10 %	3.2
20 %	3.6
30 %	3.9
40 %	4.2

A near-surface 72,000 T chromite pod in Cuba produced only a 1.4 milligal anomaly -- below normal topographic noise in many chromite-bearing areas (Wynn, 1982). Only one in ten gravity anomalies in Camaguey Province Cuba were related to gravity.

Magnetics/EM based methods.

For reasons similar to the above, magnetics and EM methods are also generally ineffective for chromite exploration. Chromite has only occasional weak magnetic susceptibility and poor conductivity. Furthermore, the hostrock generally contains highly variable contents of magnetite which is genetically independent of chromite.

Magnetics, on the other hand, might play an indirect role in chromite exploration. An increased incidence of imbrication, dike swarms, and serpentinization has been noted in the chromite-bearing areas of the Zambales Complex (Rossman, et al). This has also been observed world-wide. As remnant magnetic polarization is frequently measurable in and adjacent dikes, and since magnetite commonly develops in the serpentinite process, there is the possibility that many chromite bearing districts could be flagged by selectively-filtered aeromagnetic data. While not directly pinpointing chromite bodies, this approach could single out high probability terrains which could then be evaluated on the ground by other methods.

Serpentinite and/or intruded imbricate zones probably have an identifiable magnetic signature. Some computer experimentation on aeromag data over known chromite areas might be productive.

Geology.

So far this has been the only successful tool for podiform chromite exploration -- careful structural and compositional mapping of ultramafic rocks. This kind of work has been carried out with such expertise, and success, at the Coto and Acoje Mines that there seems little need there for outside contribution along this line presently.

Even so, geologic interpretation is more or less limited to resolving structural problems or identifying broadly-favorable chromite host environments. The main chromite prospecting guide yielded by geology is the general observation that chromite is localized within dunite zones lying within layered ultramafic sequences. Characteristically this zone intervenes between a peridotite basement, generally harzburgite or lherzolite (saxonite), and an overlying gabbro, olivine gabbro, or norite. Chromite pods are considered randomly distributed within the dunite zone (Thayer, 1979). Thrust faulting through the dunite often confuses the relationships.

In the Zambales complex there seems to be a preference of chromite for the lower parts of the dunite layer, as if the conditions for chromite accummulation were set once the magma has crystallized out most of its pyroxene, leaving nearly-pure forsterite (Fo92-94) olivine (Mg_2SiO_4) liquidus.

The chromite-bearing dunite magma should be around 33% Mg, and it appears that when chromite precipitates, whether in pods or veins, a layer of high-MgO olivine crystallizes around it, like an alteration halo, or reaction rim. Forsterite crystals up to 10cm long accompany the edges of the chromite pods at Coto (Rossman, and personal collection). Moestops (1978) describes ion exchange reactions between chromite-Mg and surrounding silicate-Fe during chromite consolidation, which probably explains

why massive chromite has higher Cr/Fe than disseminated. The relationship of MgO and Cr_2O_3 offers a promising avenue for geochemical investigation (see below).

In summary: the current geological prospecting guide for chromite is the dunite, preferably the stratigraphically lower portions of it, and possibly zones of serpentinization, diking, and increased porosity within the dunite.

Remote sensing (Strictly research at this stage).

Rossman, et al, (1959), observe: "Vegetation reflects the underlying rocks. Most peridotitic areas are grass-covered, with scattered clumps of trees or patches of brush below 2000 ft altitude. Gabbro generally supports dense forests of deciduous trees interspersed with bamboo, vines, and brush...Pine forests grow on peridotitic rocks between altitudes of 2000 and 5000 feet. The area containing the ore deposits on the reservation is grass-covered except over the easternmost ore body where brush and bamboo grow."

Raines and Wynn (1982): "It has long been known that soils developed on ultramafic rocks inhibit or completely prevent the growth of vegetation and this fact has been used to map these rocks." They go on to describe Landsat MSS compositing experiments in which they conclude that ultramafics can be accurately mapped in heavily vegetated terrains through the rendering of vegetation and limonite spectral reflectance.

There is some probability that the extremely high MgO of the chromite host rock, dunite (theoretically over 90% Mg_2SiO_4), imparts anomalous speciation or spectral reflectance upon vegetation. The use of landsat images for this is not indicated, though, because of their low resolution and the often limited areas of dunite outcrop. However, high altitude airphoto false color compositing might be effective.

Geochemistry.

The future of advanced chromite detection systems probably resides here.

Unlike most metallic ores, chromite is unaccompanied by an alteration halo (at least of the conventional type), and little seems to be known of satellite element dispersions from chromite orebodies or their vicinities. Soluble Cr dispersion from chromite seems not much studied. Hence there is currently no sense in which conventional geochemistry can be used as a chromite prospecting tool except as a crude indicator of Cr in outcrop, and then it is subject to misdirection by chromite broadly disseminated in the peridotite.

For conventional geochemical methods, heavy-mineral sampling of stream sediments can be effective in the evaluation of watersheds for outcropping ore bodies. Johnson (1982) recommends testing two characteristics: chromite grainsize and Cr/Fe ratio, both of which are known to increase in the direction of podiform orebodies. This has some potential for indicating shallowly-buried podiforms. For such analysis, laboratory procedures would have to be modified to allow evaluation of pure chromite isolated from the other heavy minerals.

Design of methods for selectively sensing soluble, as opposed to particulate, dispersion of Cr should be approached. The increased imbrication and permeability around chromite deposits would tend to enhance whatever Cr-dissolution is possible. The writer has seen soluble potassium chromate dispersed in neogene sandstones in Iran, where the only apparent source area for the sediments was the Baluchistan ophiolite belt. It is possible, though, that this Cr came from silicates.

Rodolfo Obial (pers. comm.) who is currently doing research on chromite for the Philippines' National Steel Corp., notes that more soluble Cr comes from silicates than from chromite. The presence of Cr in garnierite has been noted (Besa, pers comm).

Alterations of chromite, post cumulus and during serpentinization, are mentioned by Moeskops (1978). Park (1964), discussing the Cuban chromites at Moa, mentions apparent deuteric alteration of chromite and its replacement by non-chromiferous chlorite, which implies that the Cr has travelled. The pink Cr-chlorite, Laemmererite, and the Cr-garnet, uvarovite, are described as ubiquitous as alteration rims between pyroxene and chromite. Lapidary grade uvarovite has been collected in the Zambales (Fernandez, pers comm).

Other trace elements covariant with podiform-Cr should have been similarly influenced. In general, the subject of Cr-covariant trace elements may have been neglected.

A probably important area of inquiry is the relationship of Cr with Mg. Chromite seems universally correlated with high magnesia dunite. The Mg content of olivines associated with minable chromite versus background chromite should be researched. The lattice Cr content of these same olivines is also an obvious question.

Something was undoubtedly unique about the development of podiform chromite with respect to background disseminated chromite. Whatever this physicochemical feature was, it probably left a geochemical imprint upon the chromite and its environment and subsequent geochemical dispersions. An understanding of it could lead to the development of an effective means of locating minable chromite not in outcrop.

To date there has not been a systematic geochemical survey of the over 10,000 Sq Km of ultramafics in the Philippines. One is certainly called for. Such a survey would reveal information not only on Cr but also the other metals associated with ultramafics -- Ni, Co, Cu, Pt-metals -- and the massive sulfide group, Cu, Pb, Zn, Au, Ag, known to associate with Philippine ultramafic areas.

In advance of any large scale endeavors, however, it would be advisable to investigate the geochemical features of minable versus unminable chromite and the environment in which it occurs. A relatively inexpensive piece of research could change the whole approach to chromite exploration. Some recently developed non-conventional geochemical procedures involving selective and partial chemical analysis coupled with computerized element pattern recognition have been successful at identifying economic mineralizations that are invisible by standard geochemical and statistical procedures.

ASSISTANCE POSSIBLY NEEDED AT COTO.

There is concern at Benguet that refractory chromite may not recover apace with an eventual upswing in the world economy. To insure their competitiveness, especially against the South African product, it requires that Coto's new Lower Western Orebody (LWOB) be developed with all dispatch. Need for about $50M was mentioned. This infusion might be welcomed from U.S. industry in exchange for some sort of buying contract or participation or other arrangement as negociated.

The LWOB is a tempting orebody. Current reserve estimate:

5,149,920 T @ 34.18% Cr_2O_3
4.89% SiO_2
3.5 % SiO_2 @ -10 mesh
(lower still at finer grinds)

This should be competitive with the South African refractory (to quote one of the Coto management, "the LWOB is so good nobody could touch us").

But there is more at stake in the LWOB concept that should enter any consideration pertaining to exploration. As will be noted on the geologic map, Fig. 3, there is a north to northeast grain to the ultramafic outcrops of the Zambales. The distribution of refractory chromite (Coto) and the metallurgical chromite and Ni-Cu-Pt sulfide-bearing peridotite of Acoje are parallel to this grain, which implies that it is genetically fundamental to the the ultramafic complex. It would appear to be an imprint of the original orientation of the spread zone that brought the ultramafics to the surface. It is reasonable to expect that there should be a zone of preferred prospecting along strike of this linearity, which indeed there is. Coto-type chromite recurs for about 20-some km in this direction.

The Coto orebody swarm was developed where the Masinloc R. cut through overlying gabbro and exposed the dunite Cr-environment. Looking from here northeastward, on strike of regional trend, one is peering into hillside. The chromite environment, already buried 500 feet below outcrop on the north side of the ravine, is quickly lost to view beneath gabbro cap and continues so until it again outcrops 6 km northeast, at the Buntak orebody, where 118,379 T @ 31.57% Cr_2O_3 have been drilled out.

Dela Cruz (pers. comm.), who has been involved with the Zambales geology for over 10 years, postulates that the LWOB and the Buntak may possibly be part of a single chromite body segmented by tectonism.

The writer querried after Benguet's thoughts about possibly driving a 6 km long exploration haulage tunnel from Coto to Buntak. One is not planned. The intervening potential ore zone is at the moment

hypothetical. Some geochemical parallels along this route might make such an endeavor a good risk. It seems geologically sound.

RECOMMENDED GOVERNMENT POLICY.

There are many more small chromite mines than large ones in the Philippines. These were discovered in outcrop, are generally mined until exhausted, and then are abandoned with no further exploration (Gonzales). For the limited resources of the small miner, this is obviously wise policy, considering the totally unpredictable distribution of podiforms.

In the broader view, though, it is probable that some of these occurrences are outliers of major deposits which almost always are accompanied by minor podiforms. While the reverse is not necessarily the case, there is no way of knowing, without hard endeavor, whether an isolated pod is virtually all there is or whether it is a satellite of something the size of Coto.

It would be in the Government's interest to form a mining assistance program for the exploration of minor chromite pod vicinities, after the fashion of OME in the U.S., or KOMEP in Korea. The government assists the small miner with geological evaluation and guidance and exploration on a 50% basis. Payback is effected only in the case of success, otherwise the assistance is written off.

If only one of the 113 non-producing properties listed by Bacuta (1979) were to become a major mine from such assistance, the program will have paid for itself many times over in GNP.

METHANE GAS SEEP IN THE ZAMBALES ULTRAMAFICS.

Several kilometers east of Coto is a 5-meter diameter patch of burning methane. This was discovered in 1967, was burning then, and locals reportedly knew of it back in the '50's (Dela Cruz).

Methane emanating from ultramafics poses 3 immediate hypothetical explanations: 1) It is being created from constituents in the ultramafics -- e.g. amphibole-H_2O + CO_2 + catalyst (Pt, Ni?), 2) it is residual nonbiogenic primordial planetary methane, a la Gold et al, Cornell Univ. 3) The Zambales complex has been obducted over a hydrocarbon field. Implications are many. Exploration potential is unknown.

Coto Mine is considering making use of this free energy source.

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THE PHILIPPINE MINING SECTOR

(From 1982 Chamber of Mines Annual Report)

- Map
- Roster of members
- Production

ROSTER OF MEMBERS

REGULAR MEMBERS

1. ACOJE MINING COMPANY, INC.
   RFM Bldg.
   Pioneer St., Mandaluyong, M. M.

2. APEX MINING CO., INC.
   Ortigas Bldg.
   Ortigas Ave., Pasig, M. M.

3. ATLAS CONSOLIDATED MINING & DEVELOPMENT CORPORATION
   Soriano Bldg.
   Ayala Ave., Makati, M. M.

4. ATOK-BIG WEDGE MINING CO., INC.
   Pacific Bank Bldg.
   Aurora Blvd.
   Cubao, Quezon City, M. M.

5. BAGUIO GOLD MINING CO.
   Philex Bldg.
   Fairlane St., Pasig, M. M.

6. BENGUET CORPORATION
   Benguet Bldg.
   Pasong Tamo Ext., Makati, M. M.

7. BENGUET EXPLORATION, INC.
   Sterlinglife Condominium
   De la Rosa St., Legaspi Village
   Makati, M. M.

8. BLACK MOUNTAIN, INC.
   Bankmer Bldg.
   Ayala Ave., Makati, M. M.

9. CDCP MINING CORPORATION
   Alco Bldg.
   Buendia Ave. Ext., Makati, M. M.

10. CONSOLIDATED MINES, INC.
    Phinma Bldg.
    Salcedo St., Legaspi Village
    Makati, M. M.

11. FALCON MINERALS, INC.
    11 Castillas St., New Manila
    Quezon City, M. M.

12. FILMAG (PHILIPPINES), INC.
    11 Castillas St., New Manila
    Quezon City, M. M.

13. GOLDEN ARROW MINING CO., INC.
    Ortigas Bldg.
    Ortigas Ave., Pasig, M. M.

14. INCO MINING CORPORATION
    Asian Reinsurance Bldg.
    Salcedo St., Legaspi Village
    Makati, M. M.

15. ITOGON-SUYOC MINES, INC.
    Antonino Bldg.
    T. M. Kalaw St., Ermita, Mla., M.M.

16. LEPANTO CONSOLIDATED MINING CO.
    BA-Lepanto Bldg.
    Paseo de Roxas, Makati, M. M.

17. MANILA MINING CORPORATION
    BA-Lepanto Bldg.
    Paseo de Roxas, Makati, M. M.

18. MARCOPPER MINING CORPORATION
    Madrigal Bldg.
    Ayala Ave., Makati, M. M.

19. MARINDUQUE MINING & INDUSTRIAL CORPORATION
    MMIC Bldg.
    Pasong Tamo Ext., Makati, M. M.

20. NEW FRONTIER MINES, INC.
    Zeta Bldg.
    Salcedo St., Legaspi Village
    Makati, M. M.

21. NORTH DAVAO MINING CORPORATION
    J. Moreno Bldg.
    Gamboa St., Legaspi Village
    Makati, M. M.

22. PALAWAN QUICKSILVER MINES, INC.
    Marsman Bldg.
    Buendia Ave., Makati, M. M.

23. PHILEX MINING CORPORATION
Philex Bldg.
Fairlane St., Pasig, M. M.

24. RIO TUBA NICKEL MINING CORP.
Solid Mills Bldg.
Dela Rosa St., Legaspi Village
Makati, M. M.

25. SABENA MINING CORP.
Asian Reinsurance Bldg.
Salcedo St., Legaspi Village
Makati, M. M.

26. VULCAN INDUSTRIAL & MINING CORP.
RFM Bldg.
Pioneer St., Mandaluyong, M. M.

27. WESTERN MINOLCO CORP.
Minolco Bldg.
Salcedo St., Legaspi Village
Makati, M. M.

28. ZAMBALES BASE METALS, INC.
Salcedo Center Bldg.
Dela Costa St., Salcedo Village
Makati, M. M.

ASSOCIATE MEMBERS

29. ALAMAG PROCESSING CORPORATION
Equitable Bank Bldg.
Ortigas Ave., San Juan, M. M.

30. AZURE MINING CORPORATION
Quadstar Bldg.
Ortigas Ave., San Juan, M. M.

31. BHP OVERSEAS EXPLORATION PTY. LTD.
c/o Atty. Ethelwoldo E. Fernandez
Sycip, Salazar, Feliciano, Hernandez
& Castillo Law Offices
PAIC Bldg., Paseo de Roxas
Makati, M. M.

32. BILLITON PHILIPPINES, INC.
L & S Bldg.
1414 Roxas Blvd., Manila, M. M.

33. BOLIDEN AKTIEBOLAG - PHIL. BR.
Valderrama Bldg.
Esteban St., Legaspi Village
Makati, M. M.

34. CHROME ORE MINERALS EXPONENT, INC.
Unlad Condominium
Taft Ave., Manila, M. M.

35. FALCONBRIDGE PHILIPPINES, INC.
Alco Bldg.
Buendia Ave. Ext., Makati, M. M.

36. GLOBAL MINING RESOURCES, INC.
Alco Bldg.
Buendia Ave. Ext., Makati, M. M.

37. GOLD FIELDS ASIA LTD.
Chronicle Bldg.
Meralco Ave., Pasig, M. M.

38. GOLD FIELDS PHILIPPINES CORP.
Chronicle Bldg.
Meralco Ave., Pasig, M. M.

39. HERCULES MINERALS & OILS, INC.
Asian Reinsurance Bldg.
Salcedo St., Legaspi Village
Makati, M. M.

40. LA PLAYA MINING CORP.
Commonwealth Foods Bldg.
Buendia Ave., Makati, M. M.

41. LA SUERTE GOLD MINING CORP.
ELCO Bldg.
E. Rodriguez Sr. Blvd., Q. C., M.M.

42. MALAYAN WOOD PRODUCTS, INC.
Universal Motors Bldg.
Pasong Tamo, Makati, M. M.

43. MARSMAN AND COMPANY, INC.
Marsman Bldg.
Buendia Ave., Makati, M. M.

44. MISSION EXPLORATION COMPANY
Concorde Condominium B
Benavidez St., Legaspi Village
Makati, M. M.

45. OUTOKUMPU OY
Alexander House Bldg.
Amorsolo St., Legaspi Village
Makati, M. M.

46. PARACALE-GUMAUS CONSOLIDATED MINING CO.
APMC Bldg.
Amorsolo St., Legaspi Village
Makati, M. M.

47. PHILIPPINE EAGLE MINES, INC.
Quadstar Bldg.
Ortigas Ave., San Juan, M. M.

48. SAMAR MINING COMPANY, INC.
Elizalde Bldg.
Ayala Ave., Makati, M. M.

49. SHELL EXPLORATION (PHILS.) INC.
L & S Bldg.
Roxas Blvd., Manila, M. M.

50. SURIGAO CONSOLIDATED MINING CO., INC.
Ortigas Bldg.
Ortigas Ave., Pasig, M. M.

51. TRIDENT MINING & INDUSTRIAL CORP.
C. B. Licaros Bldg.
Muralla, Intramuros, Manila, M. M.

SPECIAL MEMBERS

52. DELFIN L. GONZALEZ
Chamber of Mines of the Phils.
Valgosons Realty Bldg.
Pasong Tamo, Makati, M. M.

53. ANTONIO G. PUYAT
AGP Management Corp.
Marvin Plaza Bldg.
Pasong Tamo, Makati, M. M.

MEMBERS' PRODUCTION

	1981	1980
A. COPPER - In MT		
Primary Producers		
1. Atlas	138,972.457	126,048.520
2. Marcopper	36,276.565	34,455.820
3. Benguet Corp.	28,092.918	25,180.194
4. Marinduque	26,613.414	19,464.133
5. Philex	22,694.952	22,080.691
6. Lepanto	15,314.453	15,231.317
7. CDCP Mining	12,244.488	20,403.790
8. Western Minolco	9,781.017	13,891.611
9. Baguio Gold	5,116.531	6,063.532
10. Acoje	2,562.696	3,121.317
11. Black Mountain	2,557.232	2,990.961
12. Sabena	176.043	9,588.590
13. Consolidated Mines	-**	6,759.337
Sub-total	300,402.766	305,279.813
Secondary Producers		
1. Zambales Base	137.837	286.079
2. Benguet Exploration	109.486	120.669
Sub-total	247.323	406.748
Total	300,650.089	305,686.561
B. GOLD - In KG		
Primary Producers		
1. Benguet Corp.	3,226.408	3,164.593
2. Atlas (Masbate)	2,534.137	1,555.791
3. Apex	1,213.216	772.072
4. North Davao	460.911	199.028
5. Vulcan	407.341	210.696
6. Benguet Exploration	374.789	371.501
7. Itogon	367.767	278.015
8. Manila Mining	150.128	148.659
Sub-total	8,734.697	6,700.355
Secondary Producers		
1. Philex	3,822.723	3,622.933
2. Atlas (Cebu)	3,500.654	3,118.558
3. Benguet Corp. (Dizon)	3,194.155	2,527.467
4. Lepanto	1,910.766	1,809.193
5. Marcopper	935.270	807.440
6. Western Minolco	574.527	727.804
7. Baguio Gold	310.055	362.980
8. Marinduque	215.660	141.330
9. CDCP Mining	77.213	117.441
10. Sabena	76.416	217.867
11. Black Mountain	55.683	89.125
12. Consolidated Mines	-**	101.249
Sub-total	14,673.122	13,643.387
Total	23,407.819	20,343.742
C. NICKEL		
1. Marinduque (Metal) - In MT	21,455.774	25,381.809
2. Rio Tuba (Ore) - In DMT	345,310	438,268

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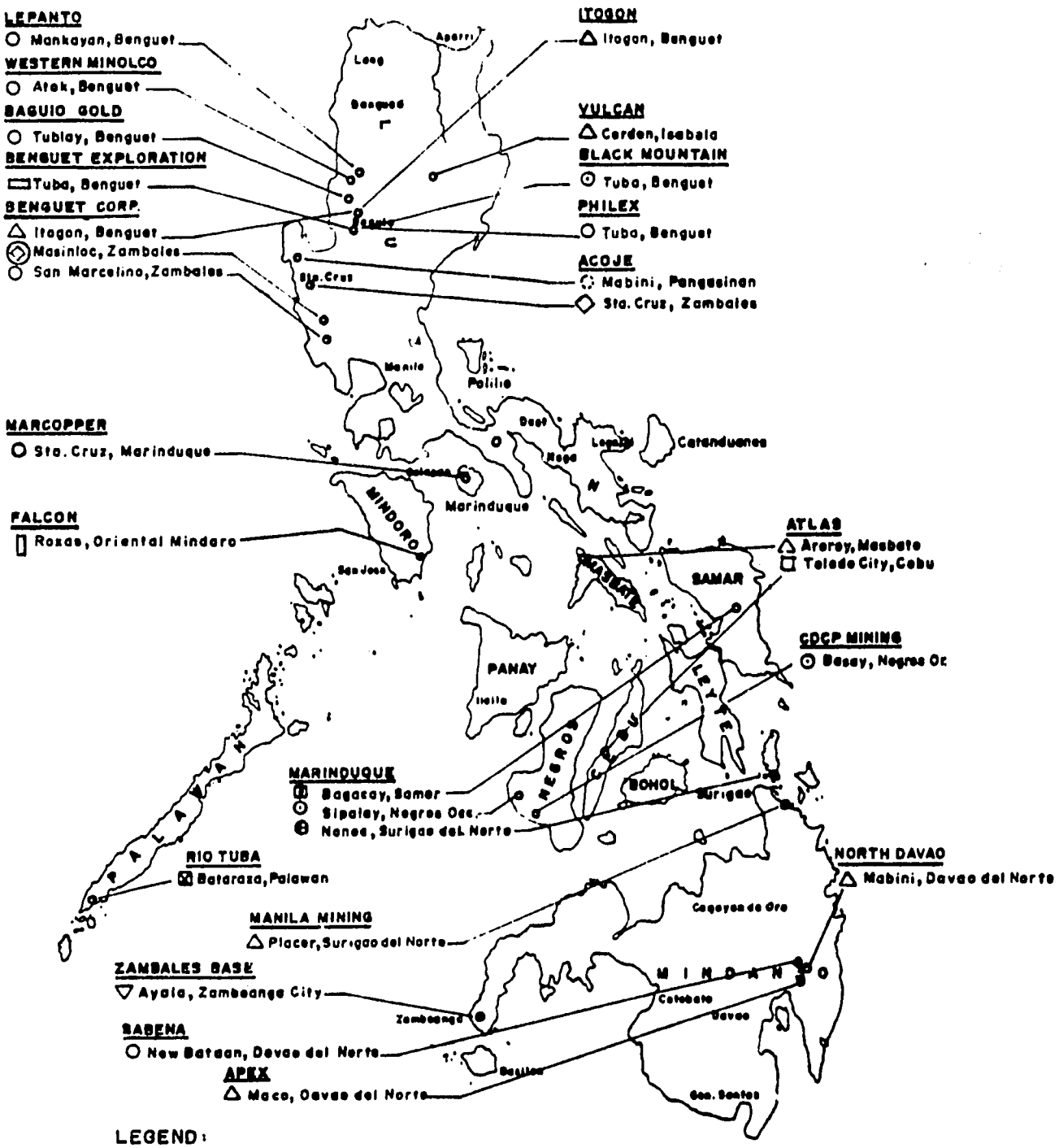
	1981	1980
D. METALLURGICAL CHROME CONCENTRATE - In DMT		
1. Acoje	90,914	92,539
2. Golden Arrow	-**	263
Total	90,914	92,802
REFRACTORY CHROME ORE & CONCENTRATE - In DMT		
1. Benguet Corp. (Consolidated Mines Contract)	269,579	340,460
E. SILVER - In KG		
1. Atlas	16,693.001	12,919.072
2. Benguet Corp.	10,353.124	9,486.722
3. Lepanto	7,741.413	7,425.151
4. Marinduque	6,308.800	5,337.030
5. Marcopper	5,860.980	5,856.400
6. Philex	4,654.922	4,216.350
7. CDCP Mining	2,663.586	4,124.781
8. Western Minolco	2,339.694	3,062.593
9. Benguet Exploration	2,003.953	2,292.328
10. Baguio Gold	1,022.480	1,265.361
11. Apex	539.211	440.460
12. Black Mountain	459.664	669.488
13. Vulcan	243.926	247.141
14. North Davao	155.471	93.742
15. Itogon	154.733	128.120
16. Manila Mining	42.010	60.505
17. Sabena	27.558	1,322.903
18. Consolidated Mines	-**	773.363
Total	61,264.526	59,721.510
F. COBALT - In MT		
1. Marinduque	998.776	1,331.540
G. ZINC - In MT		
1. Benguet Exploration	2,777.867	3,159.948
2. Zambales Base	2,455.205	3,910.170
Total	5,233.072	7,070.118
H. LEAD - In MT		
1. Zambales Base	1,015.711	1,782.048
I. MOLYBDENUM - In MT		
1. Marinduque	42.014	51.534
2. CDCP Mining	41.461	16.701
3. Black Mountain	7.138	17.713
4. Atlas	-**	2.140
Total	90.613	88.088
J. BARITE - In MT		
1. Falcon Minerals	2,135	5,560
K. PYRITE CONCENTRATE - In DMT		
1. Atlas	79,613	68,609
2. Acoje	13,895	21,598
3. Marinduque	3,214	33,748
4. Benguet Exploration	1,150	-**
Total	97,872	123,955

*All in metal except nickel ore, chrome ore & concentrate, barite and pyrite concentrate.
**No production.

LOCATION OF PRODUCING MINES



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The ore solutions generally reached the site of ore deposition along faults or related fractures. Some faults, in their earlier history, probably localized intrusives which later became hosts to the ore.

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very small distances. The systematic difference in chromite composition with mode is not confined to the Bushveld Complex. Jackson (1969) and Irvine (1967) observed the same relationships in the Stillwater and Muskox Complexes respectively. Irvine (1967) showed that changing Mg-Fe distribution between chromite and olivine (or pyroxene) along with a high silicate/chromite ratio will cause accessory chromite to gain iron, whereas olivine or pyroxene gains magnesium as a result of subsolidus exchange.

In summary, ophiolites and stratiform intrusions have large areas of ultramafic rocks that contain huge tonnages of accessory chromite. The composition of much of this chromite is such that it is of limited usefulness for metallurgical purposes. However, large areas of dunite in ophiolites are possible sources of large amounts of low-grade chromite.

Laterites

Ferruginous laterites form by weathering of an ophiolitic peridotite in a humid tropical climate having a wet/dry seasonal variation. Other conditions for development of a laterite, according to Lawrence (1974, p. 523), include: 1) an extensive, low altitude peneplane which is adequately drained; 2) block faulting and some brecciation in the peridotite to assist weathering by percolating groundwater; 3) minimum erosion in order to preserve the soil.

Of all the minerals in peridotite, chromite is least susceptible to alteration, and therefore it is concentrated in the residual soil as MgO and SiO_2 are flushed out. A typical laterite profile from New Caledonia (fig. 11, modified from Troley et al., 1979, p. 102-103) shows that Cr_2O_3, and hence chromite, is concentrated in the upper part of the laterite whereas nickel is mined from "earthy ore," "soft saprolite," "ore with boulders," and "rocky ore" units. In New Caledonia, the nickel in these units is found in a poorly defined group of hydrated magnesium silicates, and thus the nickel ore in New Caledonia is called silicate ore. However, in other localities, such as Greenvale, Australia and Moa Bay, Cuba, nickel is mined from higher units where it is found in solid solution with Fe in goethite (Lawrence, 1974, p. 526). In this case, the Ni ore is called oxide ore. Oxide ore occurs in the same units in which chromite is concentrated.

Because of the intrinsic difference in chromite compositions in dunite and harzburgite, it comes as no surprise that chromite composition in Laterites depends on the rock from which it was derived. Bulk Cr/Fe ratios are higher in Laterites derived from dunites than in Laterite derived from harzburgite (fig. 12). Note that chromite concentrates from dunites have a Cr/Fe ratio of more than 2, which is suitable for metallurgical use.

Laterites also meet the requirement that any potential source of chromium must occur in large tonnages. Table 3 shows that, as of 1975, the worldwide reserves of lateritic nickel ore were more than 3 billion tons. If the average Cr_2O_3 content is 2.5 percent (corresponding to about 5 percent chromite), known laterites contain more than 150 x 10^6 tons of chromite. If only a few percent of the known nickel-laterites occur over dunite, the chromite potential is significant.

Conclusions

Chromite will continue to be the only ore of chromium because it is the only chromium-bearing mineral that is abundant enough to satisfy industrial demand. Some common silicates, especially micas, contain as much as 5 percent chromium, but the occurrence of these Cr-enriched phases is limited and extraction of chromium from the silicate lattice is not economically feasible.

The most promising geologic environments for large, low-grade chromite deposits are dunites associated with ophiolites, metamorphosed ophiolites, and laterites developed over dunites. Because nickel is being mined from many laterites the right economic conditions could spur a number of producers to seriously consider producing chromium as a byproduct of nickel in some lateritic ores.

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APPENDIX A

TERMS USED TO DESCRIBE IGNEOUS ROCKS FORMED BY CRYSTAL ACCUMULATION*

I. Components of Rocks Formed by Crystal Accumulation

A. *Cumulus crystal = settled crystal* — A crystal (mineral) that came into existence outside of, and prior to, the magmatic sediment of which it now forms a part.

B *Postcumulus material* — primary material that formed in the places it now occupies in the magmatic sediment.

C. *Intercumulus liquid* — the liquid that occupied the interstices between the cumulus crystals before and during the growth of the postcumulus material.

II. Rocks Formed by Crystal Accumulation

A. *Cumulate = magmatic sediment* — a group name for igneous rocks formed by crystal accumulation, mainly through the action of gravity.

B. *Classification of rocks by cumulus minerals.*

1. Semiquantitative — based on cumulus crystals only; cumulus minerals are listed in order of decreasing abundance; e.g., olivine-orthopyroxene cumulate.
2. Quantitative — based on cumulus crystals only; the measured volume proportions of cumulus minerals are listed; e.g., the percentages of cumulus minerals in the cumulate are olivine 75 — orthopyroxene 25.
3. Semiquantitative — based on cumulus crystals and proportion of postcumulus material. As for B1 (above); accessory minerals are indicated in parentheses and the *type* of cumulate is defined by the volume percent of post-cumulus material as follows; <5% — *adcumulate*; 5 to 25% — *mesocumulate*; >25% — *orthocumulate*. The nature of the post-cumulus material is not indicated in the name.

III. Horizons in Cumulates

A. *Horizons* — a reference plane in a cumulate that marks a former surface of deposition:

1. *Phase contact* — a horizon marked by the appearance or disappearance of a cumulus mineral.
2. *Ratio contact* — a horizon marked by a sharp change in the proportions of the cumulus minerals.
3. *Form contact* — a horizon marked by a sharp change in the physical properties of a cumulus mineral, such as size or habit.

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* *Modified after Jackson (1967).*

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ARCHIVES OF GEOLOGICAL INFORMATION IN THE PHILIPPINES

Vast stores of geological data are available at the Bureau of Mines and Geo-Sciences library in the form of books and foreign and local publications, proceedings of seminars, technical bulletins, technical reports, maps and other.

The Library is situated at Pedro Gil (Formerly Herran), Manila. Library hours are 8:30 to 11:30 A.M. and 1:30 to 4:30 P.M., Mondays through Thursdays.

Additional to the Library, other offices of the same agency, e.g. the Geological Information Division, and the Records Section, have stores of information, some of which, however, are classified.

The Library of the Department of Geology and Geography, College of Arts and Sciences, University of the Philippines in Diliman Quezon City is open from 8:00 to 12:00 A.M., and 1:00 to 5:00 P.M., Mondays through Fridays, and from 8:00 A.M. to 1:00 P.M. Saturdays.

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The following companies offer aircraft charter, rental and leasing services:

1. Philippine Resource Helicopter, Inc.
   PADC Hangar No. 2, Domestic Airport Road
   Pasay, Metro Manila
   Tel Nos: 832-2568,-2741,-3499,

2. Philippine Aerospace Development Corporation
   PADC Hangar No. 3, MIA Avenue
   Pasay, Metro Manila
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3. Tropical Airways, Inc.
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The following individuals, encountered directly or indirectly in the course of this brief survey, were found to be a valuable resource of information on chromite, geology, and mining in the Philippines.

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PHILIPPINE COPPER DEPOSITS

M. CAMARINES NORTE					
36. Jose Panganiban, Larap	Philippine Iron Mines, Inc.	12,589,974 MT :	0.291 0.24 %Cu 0.04 %Mo 3.00 %S 10.00 %Fe	III	Stopped Operation
N. ALBAY					
37. Rapu-Rapu Island	Benguet Corporation (Rapu-Rapu Cu-Zn-Au Proj.)	3,000,000 MT :	1.81 %Cu 3.00 gmAu/MT 34.00 gmAg/MT 2.66 %Zn	II	Prospect/Under Exploration
38. Rapu-Rapu Island Korogkog	Mixbar Mining Co., Inc.	1,058,000 MT :	1.17 %Cu 2.04 gmAu/MT 14.16 gmAg/MT 30.38 %Fe 1.10 %Zn	III	Stopped Production
O. ANTIQUE					
39. Barbaza, Lumbuyan	Multi-Ore Mines, Inc.	36,255 MT :	32.625%Cu	III	Prospect/Evaluated 1977 No Activity
40. San Remigio	Electro-Copper, Incorporated (Antique Copper Project)	850,000 MT :	3.00 to 12.00 %Cu 0.74 gmAu/MT 50.00 gmAg/MT 30.00 %Fe	II	Stopped Operation 1980
P. CAPIZ					
41. Pilar, Loay	Azure Mining Corporation (Pilar Copper Property)	1,154,400 MT :	2.25 %Cu 1.40 gmAu/MT 98.70 gmAg/MT 45.10 %Mo	III	Producing

PHILIPPINE - COPPER DEPOSITS

P. CAPIZ (CONT'D)					
42. Pilar	J. Roblea and Company	92,520 MT :	0.44 %Cu	III	Prospect/No Activity
Q. NEGROS OCCIDENTAL					
43. Sipalay, Cartagena	Marinduque Mining and Ind'l. Corporation (Sipalay Copper Project)	609,576,144 MT :	0.50 %Cu	I	Producing
44. Sipalay and Cauayan	A. E. S. Mining Corporation (Umas Project)	13,608,000 MT :	0.42 %Cu	II	Prospect/Under Exploration and Development
45. Sipalay, Manlucahoc	Lepanto Consolidated Mining Co. (Hinobaan Copper Project)	90,000,000 MT :	0.40 %Cu	II	Prospect/Under Development
46. Ilog, and Asia, Bo. New Manila	Atlas Consolidated Mining and Development Corporation	27,000,000 MT :	0.35 %Cu	II	Prospect/Under Development
R. NEGROS ORIENTAL					
47. Basay, Aya-Aya	CDCP Mining Corporation (Aya-Aya Copper Project)	41,000,000 MT :	____ %Cu		Prospect/Under Exploration and Development
48. Basay, Maglinao	CDCP Mining Corporation	235,984,000 MT :	0.44 %Cu 0.284gmAu/MT 56.133gmAg/MT	I	Producing
S. CEBU					
49. Toledo City Kanapnapan, Camp 8	Jel Mining and Development Corp.	226,840 MT :	0.50 %Cu 7.28 %Zn	III	Prospect/Under Exploration
50. Toledo City Lotupan	Atlas Consolidated Mining and Development Corporation	942,487,000 MT :	0.45 %Cu	I	Producing

PHILIPPINES COPPER DEPOSITS

T. LEYTE					
51. Tacloban City Suhi	Argonaut Mining Exploration, Incorporated	2,025,000 MT :	2.50 %Cu	II	Prospect/No Activity
U. WESTERN SAMAR					
52. Minabangan, Bagacay	Marinduque Mining and Ind'l. Corporation (Bagacay Copper Project)	1,424,973 MT :	2.40 %Cu 2.32 %Zn	II	Operation Suspended 1981
V. EASTERN SAMAR					
53. Sulat, Taft, San Oulian and Minabangan	Trident Mining and Ind'l. Corp. (Samar Copper Project)	32,500,000 MT :	0.61 %Cu 0.62 gmAu/MT 21.00 gmAg/MT	II	Prospect/Under Exploration and Development
W. ZAMBOANGA DEL SUR					
54. Zamboanga City, Ayala District	Zambales Base Metals, Inc.	5,904,520 MT :	0.30 %Cu 2.50 %Pb 3.00 %Zn	III	Producing
55. Dumingag, Bos. Guripan, Mahayag and Lipawan	Surigao Consolidated Mining Compnay, Incorporated	137,000 MT :	2.18 %Cu	III	Prospect/No Activity
X. AGUSAN DEL NORTE					
56. Cabadbaran, Jabonga and Santiago	Jose Fernandez	100,000,000 MT :	0.45 %Cu	II	Prospect/Under Exploration
57. Santiago	Asiga Mining Corporation	71,000,000 MT :	0.36 %Cu	II	Prospect/Under Exploration
Y. SURIGAO DEL SUR					
58. Lanuza, Balabay	Surigao Minerals Acres Association	103,475 MT :	3.90 %Cu	III	Prospect/No Activity

PHILIPPINE COPPER DEPOSITS

Z. DAVAO DEL NORTE

59.	Maco, Masara	Apex Mining Company, Inc. (Mapula Copper Project)	12,712,927 MT :	0.44 %Cu	II	Prospect/Under Exploration and Development
60.	Mabini, Masara, Amacan	North Davao Mining Corporation (Amacan Copper Project)	160,700,000 MT :	0.37 %Cu 0.17 gmAu/MT	I	Prospect/Under Exploration and Development
61.	New Bataan, Bo. Camanlangan	Sabena Mining Corporation	75,482,198 MT :	0.44 %Cu 0.53 gmAu/MT	II	Suspended Operation 1981
62.	Mabini, Maraut, Hijo	North Davao Mining Corporation (Hijo Gold Project)	473,220 MT :	0.44 %Cu 8.14 gmAu/MT 2.00 gmAg/MT	III	No Copper Production 1981
63.	Pantukan	Sta. Barbara Mining Co., Inc. (Inax Copper Deposit)	56,000,000 MT :	0.43 %Cu	II	Prospect/Under Exploration

AA. SOUTH COTABATO

64.	Dumanus, Palomolok	Samar Mining Company, Inc.	350,000 MT :	1.75 %Cu	III	Prospect/Under Exploration

BB. PALAWAN

65.	Balabac	Benguet Corporation	80,000 MT :	3.40 %Cu 43.00 %S	III	Stopped Operation

S U M M A R Y

No. of Producing Mines - 15

No. of Mines that Stopped and/or suspended operation - 12

No. of Prospects - 38

TOTAL ESTIMATED RESERVES - 4,33.,812,681 MT

PHILIPPINE GOLD-SILVER DEPOSITS

LOCATION	OWNER/OPERATOR	ESTIMATED RESERVES Tonnage	ESTIMATED RESERVES Grade	ECAFE CLASSIFICATION	STATUS
A. ABRA					
1. Baay-Licuan	Abra Mng. & Ind. Corporation*	318,350	9.09 gmAu/MT	III	Prospect
2. Plas, Baay-Licuan	Patok-Gold-Copper Prospects*	-	-		Prospect
3. Patok, Baay-Licuan	Discovery Mines Enterprises	-	-		Prospect
B. KALINGA-APAYAO					
4. Balbalasang, Balbalan	Lepanto Exploration Asia	-	-		Prospect
5. Balatoc, Pasil	Mountain Mines, Incorporated	-	-		Prospect
6. Balatoc, Pasil	Batong-Buhay Gold Mines, Inc.*	107,013,469	0.25 gmAu/MT 2.71 gmAg/MT 0.60 % Cu	II	Prospect (Pre-war operating Mine)
C. BENGUET					
7. Suyoc, Mankayan	Itogon-Suyoc Mines, Inc.*	689,687	4.276 gmAu/MT	III	Formerly operating
8. Mankayan	Mankayan Mineral Dev't Co., Inc.	50,000,000	0.62 gmAu/MT	II	Prospect
9. Palasan, Mankayan	Polar Mines, Incorporated	100,000,000	0.40 gmAu/MT	II	Prospect
10. Lepanto, Mankayan	Lepanto Cons. Mng. Company (Mankayan Mines)	5,686,900	3.30 gmAu/MT 2.42 % Cu	II	Producing
11. Sinipalp, Bakun	Trans-Asia Oil & Dev't Co.	-	Trace to 70.00 gmAu/MT		Prospect
12. Tublay	King Solomon Mines*	-	-		Prospect

*Primary Gold Mines and Prospects

PHILIPPINE GOLD-SILVER DEPOSITS

C. BENGUET (CONT'D)					
13. Tublay	Caponga Gold Prospect*	-	-		Prospect
14. Tublay	Baguio Gold Mng. Co. (Sto Nino Mines)	57,803,678	0.32 gmAu/MT	II	Formerly operating
15. Tublay	Ambassador Claims	-	-		Prospect
16. Boneng, Atok	Western Minolco Corp.* (Boneng Gold Project)	2,000,000	0.45 gmAu/MT	III	Prospect
17. Boneng, Atok	Western Minolco Corp. (Boneng Copper Project)	135,283,523	0.56 gmAu/MT	II	Formerly operating
18. Caliking, Atok	Worldwide Minerals & Ind. Corp.	111,526,000	0.17 gmAu/MT 3.11 gmAg/MT	II	Prospect
19. Atok	Atok-Big Wedge Mng. Co., Inc.*	-	-		Producing
20. Tuba, Itogon	Demonstration Mine*	-	-		Formerly operating
21. Itogon	Phil. Mng. Syndicate	-	-		Prospect
22. Sangilo, Itogon	Itogon-Suyoc Mines, Inc.*	980,462	4.20 gmAu/MT	III	Producing
23. Sangilo, Itogon	Itogon-Suyoc Mines, Inc.*	175,261	5.248gmAu/MT	III	Prospect
24. Gumatdang, Itogon	Chicé Mines, Inc.*	4,049,120	10.09 gmAu/MT	II	Prospect
25. Macawiwili, Itogon	Omico Mng. & Ind. Corp.* (Macawiwili Project)	1,552,540	11.44 gmAu/MT 40.09 gmAg/MT	II	Prospect
26. Itogon	Belle Mng. & Oil Exp'l., Inc.	-	-		Prospect
27.	Benguet Corporation* (Kelly Mine)	-	-		Producing

*Primary Gold Mines and Prospects

PHILIPPINE GOLD-SILVER DEPOSITS

C. BENGUET (CONT'D)					
28. Balatok, Itogon	Benguet Corporation* (Acupan Mine)	4,192,720 :	5.41 gmAu/MT	II	Producing (Includes those of Acupan, Antamok, Atok, and Kelly Mines)
29. Itogon	Benguet Corporation* (Antamok Mine)	- :	-		Producing
30. Paedal, Tuba	Philex Mng. Corporation	204,826,000 :	0.56 gmAu/MT 0.52 % Cu	I	Producing
31. Camp 6, Kennon Rd., Tuba	Benguet Exploration, Inc.* (Thanksgiving Mine)	488,911 :	3.93 gmAu/MT 34.26 gmAg/MT 0.58 % Cu 3.79 % Zn	III	Producing
32. Becker	Goldfields Asia	- :	-		Prospect
D. ISABELA					
33. Marian, Gordon	Vulcan Ind. & Mining Corp.*	1,861,720 :	7.00 gmAu/MT	II	Operating
E. NUEVA VIZCAYA					
34. Kayapa	Divina Timber & Mineral Res., Inc.	40,000,000 :	0.241gmAu/MT 0.56 % Cu	III	Prospect
35. Quezon, Kongono	Fil-Am Resources, Inc.* Golden Arrow Mining Co., Inc.*	5,212,374 :	2.03 gmAu/MT	II	Prospect
F. NUEVA ECIJA					
36. Galazor, Carranglan	Bulo-Bihaho Gold Placer Deposits	- :	-		Prospect
37. Burgos, Carranglan	Masinga-Mabitbitao Gold Placer Deposit	- :	-		Prospect

PHILIPPINE GOLD-SILVER DEPOSITS

G. ZAMBALES					
38. Poa, San Marcelino	Dizon Copper-Silver Mines, Inc.	82,489,000 :	1.07 gmAu/MT 0.42 % Cu	II	Producing
H. PAMPANGA					
39. Pabanlag, Florida Blanca	C. M. Dizon and Associates*	34,818 :	1.92 gmAu/MT	III	Prospect
40. Pabanlang, Florida Blanca	Pabanlang Gold Prospect*	- :	0.44 gmAu/MT 4.08 gmAg/MT		Prospect
I. BULACAN (CONT'D)					
41. Norzagaray	Ipo Gold Mines*	- :	-		Formerly operating
42. Sta Maria	Sta Maria Gold Placer Deposits*	- :	-		Prospect
43. Salakot, Norzagaray	Salakot Gold Deposits*	- :	-		Prospect
44. San Jose del Monte	Construction Aggregates Producers Company*	25,000,000 :	3.00 gmAu/MT 43.47 % Fe 9.50 % TiO_2	II	Prospect
J. RIZAL					
45. Puray, Montalban	Lourdes Tanesa Placer Mng. Claims	- :	-		Formerly operating
46. Sta Inez, Antipolo	Angelo Gold Deposits	- :	-		Prospect
47. Sta Inez, Tanay	Tayabasan-Gagaitan Gold Placer Prospect	- :	-		Prospect

PHILIPPINE GOLD-SILVER DEPOSITS

K. QUEZON					
48. Infanta	Copper Belt Mining Corp.	500,000 :	0.857gmAu/MT	III	Prospect
L. CAMARINES NORTE					
49. Gumaoa, Paracale	Paracale Gumaon Consolidated Mining Co., Inc.*	492,840 :	7.10 gmAu/MT	III	Formerly operating
50. J. Panganiban	San Mauricio Mining Co.* (Phil. Eagle Mines, Inc.*)	2,924,000 :	13.75 gmAu/MT 17.00 GmAg/MT 0.24 % Pb 0.26 % Zn	II	Formerly operating
51. Tugos, Paracale	Armstrong Mining & Ind. Corp.*	- :	-		Formerly operating
52. Sta Rosa, J. Panganiban	Mambulao Consolidated Mines*	- :	-		Formerly operating
53. Paracale	United Paracale Mining Co.*	1,350,000 :	14.00 gmAu/MT	II	Formerly operating
54. J. Panganiban	Sta Barbara Mining Co.*	35,000 :	15.02 gmAu/MT	III	Formerly operating
55. Sta Rosa, J. Panganiban	La Suerte Gold Mining Co.* (Sta Rosa Mines)	456,000 :	7.60 gmAu/MT	III	Prospect
56. Bagong-Bayan,	Conrad Leviste*	1,503,000 :	0.66 gmAu/MT	III	Prospect
57. Paracale	Golden River Mining Corp.* (Paracale Gold Project)	57,358,496 :	-		Producing
58. Poblacion, J. Panganiban	Phil. Clay Mining Corp.*	1,311,000 :	4.11 gmAu/MT	III	Prospect
59. Basud, Paracale	River Bed Mining Exp'l., Inc.*	- :	-		Prospect
60. Paracale	Maromao Gold Prospect*	- :	-		Prospect
61. Parang, Paracale	Magna Mines*	- :	-		Prospect

PHILIPPINE GOLD-SILVER DEPOSITS

L. CAMARINES NORTE (CONT'D)					
62. Labnig, Paracale	Golden Rock Mines, Inc.*	- :	-		Prospect
63. Luya, Aroroy	Luya Gold Prospect*	- :	-	Prospect	Prospect
64.	Tuba Gold Prospect*	- :	-		Prospect
65. Exciban, Labo	Exciban Gold Prospect*	- :	-		Prospect
66. Malaya, Labo	Tuba Mines*	- :	-		Formerly operating
67. Exciban, Labo	Nalenbitan Gold Project*	- :	-		Formerly operating
68. Basud	Rosman Minerals, Inc.*	500,000 :	3.10 gmAu/MT	III	Formerly operating
69. Labo	Elron Minerals, Inc.* (Labo Gold Project)	1,340,000 :	2.19 gmAu/MT		Prospect
M. CAMARINES SUR					
70. Caramoan, Gata	Rajah Lahuy Mng. Co., Inc.*	2,043,593 :	10.00 gmAu/MT	II	No production 1981
N. ALBAY					
71. Rapu-Rapu Island	Rixbar Mng. Co., Inc.*	1,058,000 :	2.04 gmAu/MT 14.16 gmAg/MT	II	Formerly operating
72. Rapu-Rapu Island	Bonguet Corporation*	5,000,000 :	5.00 gmAu/MT 54.00 gmAg/MT 1.81 % Cu 2.66 % Zn	III	Under exploration 1981
O. BATANGAS					
73. Taysan	Taysan Copper Mines, Inc.	119,400,000 :	0.55 gmAu/MT	III	Formerly operating
74. Lobo	Copper Belt Mining Corp.	90,370 :	20.57 gmAu/MT	III	Formerly operating

*Primary Gold Mines and Prospects

PHILIPPINE GOLD-SILVER DEPOSITS

P. MINDORO ORIENTAL		-	: -		Prospect
75. San Teodoro	Superior Mining & Ind. Corp.*				
Q. MARINDUQUE					
76. Tapian, Sta Cruz	Marcopper Mining Corporation	95,800,000	: 0.11 gmAu/MT 6.62 gmAg/MT 0.44 % Cu	II	Producing
R. MASBATE					
77. Aroroy, Capsay	Mountain Mines, Inc.*	992,250	: 9.26 gmAu/MT 24.51 gmAg/MT	II	Prospect
78. Aroroy	Atlas Cons. Mng. & Dev't Corp.*	8,771,000	: 2.166gmAu/MT	II	Producing
S. EASTERN SAMAR					
79. San Julian	Trident Mng. & Ind. Corp. (Samar Project)	32,500,000	: 0.62 gmAu/MT 21.00 gmAg/MT 0.61 % Cu	II	Prospect
T. ANTIQUE		850,000	: 0.74 gmAu/MT	III	Formerly operating
80. San Remigio	Electro-Copper				
U. CAPIZ					
81. Lo-ay, Pilar	Azure Mining Corp.	1,154,000	: 1.46 gmAu/MT 2.15 % Cu 98.70 gmAg/MT	III	No gold production

*Primary Gold Mines and Prospects

PHILIPPINE GOLD-SILVER DEPOSITS

V. NEGROS OCCIDENTAL					
82. Basay	CDCP Mining Corporation	235,984,000 :	0.284 gmAu/MT 56.14 gmAg/MT 0.44 % Cu	I	Producing
W. SOUTHERN LEYTE					
83. San Ricardo	Pinut-an Gold Prospect	- :	-		Formerly operating
X. SURIGAO DEL NORTE					
84. Mabini	A. Soriano Corporation*	70,200,000 :	0.19 gmAu/MT	II	Prospect
85. Mabuhay, Sison	Mindanao Expl. & Dev. Corp.* (Mindanao Mother Lode Mines)	161,514 :	0.41 gmAu/MT	III	Formerly Operating
86. Mainit, Siana	Surigao Cons. Mng. Co., Inc.	4,573,396 :	5.08 gmAu/MT	II	Producing
87. Tinabingan, Placer	Manila Mining Corporation*	836,900 :	6.26 gmAu/MT	III	Producing
Y. AGUSAN DEL NORTE					
88. Del Pilar, Cabadbaran	Manila Mining Corp.*	- :	-		Formerly operating
Z. MISAMIS ORIENTAL					
89. Cagayan de Oro City	Golden Arrow Mng. Co., Inc.*	18,416,160 :	-		Prospect
90. Pigsag-an, Cagayan de Oro City	Jao Co. & Asso.*	- :	-		Formerly operating
AA. SURIGAO DEL SUR					
91. Barobo, Bahi	Rosario Mng. & Dev. Co.*	754,000 :	-		Prospect

*Primary Gold Mines and Prospects

PHILIPPINE GOLD-SILVER DEPOSITS

BB. AGUSAN DEL SUR					
92. Rosario	Agusan Cons. Mng. Co., Inc.	10,033 :	11.06 gmAu/MT	III	Prospect
CC. ZAMBOANGA DEL SUR					
93. Labangan, Noboran	Senora Stones, Ltd.*	2,591,207 :	0.423gmAu/MT	III	Formerly operating
94. Curuan, Mina	Carmen Mindanao Mng. Co., Inc.*	184,161,400 :	8.93 gmAu/MT	I	Formerly operating
DD. DAVAO DEL NORTE					
95. Masara, Maco	Apex Mining Co., Inc.* (Masara Gold Project)	4,077,973 :	9.035gmAu/MT	II	Producing
96. Hijo, Maraut, Mabini	North Davao Mng. Co., Inc. (Hijo Gold Project)	473,220 :	8.14 gmAu/MT 2.00 gmAg/MT 0.44 % Cu	III	Producing
97. Amacan, Masara, Mabini	North Davao Mng. Co., Inc. (Amacan Copper Project)	160,700,000 :	0.17 gmAu/MT	II	Formerly operating
98. Cawanlangan,	Sabena Mining Corporation	15,594,684 :	1.725gmAu/MT	II	Formerly operating

S U M M A R Y

No. of Producing Mines:	18
No. of Mines that stopped and/or suspended operation:	29
No. of Prospects:	51
TOTAL ESTIMATED RESERVES:	1,954,139,149 MT

PHILIPPINE IRON DEPOSITS

LOCATION	OWNER/OPERATOR	ESTIMATED RESERVES Tonnage MT	ESTIMATED RESERVES Grade	ECAFE CLASSIFICATION	STATUS
A. ILOCOS NORTE					
1. Piddig-Lamain	Ilocandia Iron & Smelting	850,000	60.50% Fe	III	Prospect
2. Laoag	Laoag Magnetite Sand Deposits	---	0.35%-13.65% Mag. Fraction		Prospect
3. Paoay	Paoay Magnetite Sand Deposit	---	1.70%-9.40% Mag. Fraction		Prospect
4. Tukak	Tukak Iron Deposits	lode	---		Prospect
5. Nueva Era, Cabittauran	Phil. Processing Corp.	102,600	52.56% Fe	III	No mining operation
B. CAGAYAN					
6. Claveria	Claveria Iron Deposits	---	66.55% Fe 0.09% Al_2O_3 14.90% SiO_2		Prospect
7. Abulug, Pamploma	Feve Mining Corp.	11,540,000	59.91% Fe 6.87% SiO_2	II	Operation suspended No mining operation
8. Calamantungan, Dawang	Elizalde & Co.	1,222,552	51.00% Fe	III	No mining operation
9. Gonzaga, Bo. Batarangan	Apex Exp'l & Mng. Co., Inc.	18,596,000	32.26% Fe	II	Under exp loration
10. Sanchez-Mira, Abulug Ballesteros, Appari	Del Mar Mng. Dev't Corp. (Under operating agreement w/ Inco Mining Corp.-Operator)	9,480,000	58.95% Fe 7.00% TiO_2	II	Operation suspended

PHILIPPINE IRON DEPOSITS

B. CAGAYAN					
11. Ballesteros	E.M. Ramos & Co., Inc.	2,100,000	53.17% Fe	III	Prospect
C. LA UNION AND ILOCOS SUR					
12. Sta Cruz & Sta Lucia Ilocos Sur and Bacnotan, La Union	Filmeg (Phil.), Inc.	2,139,780	58.60% Fe	III	Stopped operation
D. LA UNION					
13. Damortis, Lingayen Gulf	Anglo-Phil. Oil & Mng. Corp.	2,031,400	60.11% Fe 8.22% TiO_2	III	Stopped operation
E. QUEZON					
14. Dipacucao- Casiguran	Maraveni Cons. Mines, Inc.	1,427,860	55.00% Fe	III	Ceased operation
F. TARLAC					
15. Burgos & Mayantoc Bibiga	P.D. Ago Mng. Exp'l Co.	153,800	39.50% Fe	III	Prospect
G. ZAMBALES					
16. Sta Cruz	Global Mng. Resources, Inc. (Laterite Mng. & Nickel Dev't Corporation)	55,000,000	17.24% Fe 1.75% Ni 0.04% Co	II	Under exploration
H. BULACAN					
17. San Jose del Monte Dulong Bayan	Construction Aggregates Producers Co.	25,000,000	43.47% Fe 9.50% TiO_2 3.00% gmAu/MT	II	Producing
18. Doña Remedios Trinidad	J. and J. Enterprises (Jorge Eguorra-Operator)	2,000,000	82.00% Fe_2O_3	III	No production '81
19. San Ildefonso, Camaching	Mrs. Carmen Vda de Villaroal	2,000,000	55.52% Fe	III	No mining operation

PHILIPPINE IRON DEPOSITS

H. BULACAN					
20. Doña Remedios Trinidad	Oro Dev't Corporation	22,850,000	62.06% Fe	II	No production '81
I. BATAAN					
21. Morong	Long Beach Mining Corp.	628,551	51.10% Fe	III	Stopped production '74
J. RIZAL					
22. Antipolo, Sta Ines	Sta Ines Mng. & Steel Corp.	33,490,380	48.86% Fe 4.20% S	II	No production
K. CAMARINES NORTE & QUEZON					
23. Mt. Kadig	Horizon Mineral & Oil Corp.	83,129,840	30.00% Fe	II	Geological/ Explored
L. MINDORO OCCIDENTAL					
24. Abra de Ilog, Bo. Nagsabonyan	Long Year Mng. Co., Inc. (Under operating agreement w/ Hercules Cons. Mng. Co.-Owner)	2,600,000	66.32% Fe	III	Under exploration
25. Abra de Ilog	Hercules Cons. Mining Corp.	1,840,713	66.32% Fe	III	No mining operation
26. Mamburao & Puerto Gallera	Fernandez-Hermanos, Inc.	6,000,000	55.00% Fe	II	Under development/Target date of Operation is 1984
M. MARINDUQUE					
27. Mogpog, Maganan	Marinduque Iron Mines	287,000	55.35% Fe	III	No mining operation

PHILIPPINE IRON DEPOSITS

N. CAMARINES NORTE					
28. Capalonga and Mataque	Manzana and Pabilona Group	1,711,160	57.68% Fe	III	No mining operation
29. Capalonga & Mataque	Century Iron Mines, Inc.	1,171,620	58.87% Fe	III	No mining operation
30. Jose Panganiban, Larap	Phil. Iron Mines, Inc.	12,589,974	10.00% Fe 3.00% FeS_2 0.29% Cu 0.04% Mo	II	Ceased operation
31. Paracale, Calabarnay	Agusan Gold Mines, Inc.	451,376	57.80% Fe	III	Evaluated '78 No recent report of activity
32. Labo	Maraveni Mining Co., Inc.	1,000,000	57.00% Fe	III	No mining operation
33. Labo, Napaod	Vein Venida, Incorporated	100,000	55.00% Fe	III	No mining operation
34. Talisay & Vinson	Zen Mining Exp'l Corp. (Under operating agreement w/ FILMAG(Phil.), Inc.)	2,500,000	60.00% Fe	III	Explored
O. CAMARINES SUR					
35. Tinambac, Pantat	Yupegoz Mining Corp.	1,649,300	50.32% Fe	III	Evaluated '69/ Explored
36. Lagonoy	Hercules Iron Mines Dev., Inc.	300,000	56.00% Fe	III	Explored
P. ALBAY					
37. Napu- Napu Is. Acal	San Ramon Mining Company	17,500	43.33% Fe	III	No mining operation

PHILIPPINE IRON DEPOSITS

Q. LEYTE					
38. Tacloban City, Paco Tanauan	Great Pacific Mining Corp.	2,255,000	59.36% Fe	III	No operation
39. Tolosa	Inco Mining Corporation	40,662,462	17.29% Fe	II	Operation Suspended
40. Abuyog & McArthur	Phil. Mineral Sands & Co. (Inco Mining Corp.-Operator)	917,730	59.39% Fe 4.40% TiO_2	III	Operation suspended
R. EASTERN SAMAR					
41. Borongan, Hibacong	G.Y. Ornopia & Son's, Inc. (Laterite Iron Ore)	12,303,122	39.44% Fe	II	No operation
42. Gen. McArthur	Gen. McArthur Iron Deposit (Laterite Iron Ore)	1,131,990	58.48% Fe	III	Prospect
43. Manicani, Guian	Palawan Syndicated Ventures, Inc.	7,652,963	37.61% Fe 1.63% Ni	II	Under exploration
S. PALAWAN					
44. Narra, Pulot	Olympic Mines & Dev't Corp. (Laterite Iron Ore- Pulot Nickel Proj.-Under operating agreement w/ Winchester Exp'l Corp.-Claimowner)	2,631,168	22.25% Fe [illegible]	III	Evaluated *73/ Under exploration
45. Narra, Bato-Bato	Olympic Mines & Dev't Corp. (Toronto Nickel Proj.-Under operating agreement w/Toronto Exp'l Corp.-Claimowner - Laterite Iron Ore)	3,670,712	20.69% Fe [illegible]	III	Under exploration
46. Narra, Calutogan	Olympic Mines & Dev't Corp. (Under operating agreement w/ Sta Monica Exp'l. Corp.)	1,752,000	58.00% Fe 2.03% Ni	III	Under exploration

PHILIPPINE IRON DEPOSITS

S. PALAWAN					
47. Bataraza, Rio Tuba	Rio Tuba Nickel Mng. Corp.	47,597,656	32.65% Fe	II	Explored
48. Quezon & Aborlan	A. Soriano V. Cia(Lat. Iron Ore)	91,082,970	41.118% Fe 1.158% Ni 2.208% MgO 0.137% Cu	II	Prospect
49. Brooke's Pt., Ipilan	Infanta Minerals & Ind'l Corp. (Laterite Iron Ore)	2,513,000	22.25% Fe 2.20% Ni	III	Prospect
50. Brooke's Pt. Ipilan	Palawan Nickel Corporation (Laterite ron Ore)	6,149,457	28.66% Fe 1.75% Ni	II	Evaluated '71/ Prospects, Explored
T. ILOILO					
51. Guimaras Is., Nueva Valencia	J. Nobles & Co., Inc.	1,800	51.75% Fe	III	Explored
U. CEBU					
52. Takaan, Cebu City	Talamban Iron Deposit	---	42.9-50.77% Fe 23.8-33.72% SiO_2		Prospect
V. NEGROS OCCIDENTAL					
53. Sipalay	Gabun-Paracale Mng. Co., Inc.	44,192	39.59% Fe	III	No mining operation
W. ORIENTAL NEGROS					
54. Southern Part	A.T. Escaño Mining Corp.	10,493,000	62.50% Fe	II	No operation
55. Mun. of Basay, Dayawan, Sta Catalina Sluton & Zamboangulta	Inco Mining Corp.	6,596,067	17.96% Fe	II	Operation suspended

PHILIPPINE IRON DEPOSITS

X. SURIGAO DEL NORTE					
56. Dinagat Island	Government Reservation (Al. laterite)	32,634,009	18-60% Al_2O_3 10.86% SiO_2	II	Partially explored
57. Nonoc Island	Government Reservation (Al. Laterite)	17,100,000	50.65% Fe 18.18% Al_2O_3 2.25% SiO_2	II	Partially explored
58. Nonoc Island	Marinduque Mining & Ind'l Corp. (Laterite Iron Ore)	67,118,309	37.48% Fe [illegible] % Ni [illegible] % Co	II	No production
59. Dinagat, Awasan	Surigao Nickel Reservation (Laterite iron ore)	387,712,048	44.98% Fe [illegible] % Ni [illegible] % Co	I	Evaluated '68
60. Bucas Grande Is.	Government Reservation (Al. Laterite)	242,196,400	41.64% Fe 21.53% Al_2O_3 2.47% SiO_2	I	Partially explored
61. Tagana-an, Bo.	Hinatuan Mining Corporation (Laterite Iron Ore)	1,485,113	12.80% Fe 2.25% Ni 0.09% Co	III	Evaluated '80
Y. SURIGAO DEL SUR					
62. Carrascal, Adlay	P.D. Ago Enterprides (Carrascal-Puthaw Ass'n Lessee)(Laterite Iron Ore)	14,000,000	48.00% Fe 0.56% Ni	II	Under exploration
63. Hinatuan, Bo. Soriano	Intercontinental Minerals Res.	2,000,000	64.44% Fe	III	No operation
Z. ZAMBOANGA DEL SUR					
64. Mosalip, Aurora Zamboanga del Sur	Midsalip Iron Deposit	---	---		Prospect
65. Bayog, Sibuguey	Zambalon Base Metals, Inc. (Sibuguey Iron Proj.-Under operating agreement w/Samar Mining Co.-Owner)	2,841,015	49.80% Fe	III	No operation

PHILIPPINE IRON DEPOSITS

Z. ZAMBOANGA DEL SUR					
66. Bonawan	Surigao Consolidated Mng. Co., Inc. (Pioneer Project-Under operating agreemnet with Pagadian Iron Mine)	5,859,688	48.87% Fe 2.00% S	II	No operation
AA. SOUTH COTABATO					
67. Sarangani, Bay	Liberty Mines, Incorporated	4,000,000	60.00% Fe	III	Explored

S U M M A R Y

No. of Producing Mines:	1
No. of Mines that stopped and/or suspended operation	31
No. of Prospects	35
TOTAL NO. OF ESTIMATED RESERVES:	1,320,523,277 MT

PHILIPPINE MANGANESE DEPOSITS

LOCATION	OWNER/OPERATOR	ESTIMATED RESERVES Tonnage	ESTIMATED RESERVES Grade	ECAFE	STATUS
A. ILOCOS NORTE					
1. Siec	Siec Manganese Deposits	24,150	40.00% Mn	III	No mining operation
B. KALINGA APAYAO					
2. Calanasan	Armstrong Mining & Ind'l Corp.	3,000	45.00% Mn	III	Stopped operation
C. TARLAC					
3. Capas, O'Donnel	Phil. Base Metals Inc.	175,000	40.00% Mn	II	No mining operation
4. Capas	G and R Mng. Expl Co., Ltd.	15,000	45.50% Mn	III	Prospect/Under exploration
D. NUEVA ECIJA					
5. Caranglan, Bo. Maringalo	Vicente G. Abubo	9,710	47.00% Mn	III	Producing
6. Laur	Laur Manganese Mng. Co., Inc.	5,000	46.00% Mn	III	No mining operation
7. Gabaldon, Ligaya	Sunrise Mng. Company	9,750	37.91% Mn	III	No mining operation
8. Gabaldon	J. A. Bacaltos & Asso. Co.	55,799	43.00% Mn	II	Stopped production
E. QUEZON					
9. Baler, Madulog	Pan Asia Mining Corp.	174,640	47.67% Mn	II	No mining operation
F. MARINDUQUE					
10. Sta Cruz	Phil. Base Metals, Inc.	100,000	42.00% Mn	II	Ceased operation 1960

PHILIPPINE MANGANESE DEPOSITS

G. CAMARINES SUR					
11. Siruma, Bo. Bobuan	Eduardo S. Puzon	20,000	45.00% Mn	III	Prospect/Under exploration
H. PALAWAN					
12. Coron, Busuanga Is.	Palawan Mining Corp.	10,000	47.00% Mn	III	No operation
13. Coron	Fernandez-Hermanos, Inc.	6,000,000	50.00% Mn	I	Prospect/Under exploration
14. Coron, San Nicolas	Jordan Mng. & Ind'l Corp.	137,340	0.65-48.87% Mn 12.05-75.35% SiO_2 0.92-2.44% Al_2O_3 3.42% Fe 0.105% S 0.10% P	II	Prospect/No
15. Coron, Busuanga Is.	Jacal Mining Corp.	11,050	46.00% Mn	III	Ceased operation 1960
I. MASBATE					
16. Aroroy	Phil Base Metals, Inc.	2,102	46.00% Mn	III	Stopped productiion 1970
17. Mandaon, Aroroy & Milagros	Surigao Development Corp.	108,385	51.00% Mn	II	Prospect/Evaluated 1968/No activity
18. Milagros, Taisan	Juanito Espina	210,000	50.36% Mn	II	Stopped production
J. WESTERN SAMAR					
19. San Jose de Buan	Rizal Exploration Co.	3,678	35.00% Mn	III	Prospect/Evaluated 1969/No activity
20. Tinambakan, Pina	Phil. Base Metals, Inc.	14,886	32.00% Mn	III	No mining operation
K. NEGROS ORIENTAL					
21. Larena & Ma. Siquijor	Zambales Base Metals, Inc.	119,583	28.00% Mn	II	Ceased operation since 1963

PHILIPPINE MANGANESE DEPOSITS

L. SIQUIJOR					
22. Muns. of Larena, Maria & Enrique Villanueva	New Frontier Mines, Inc.	117,447	33.61% Mn	II	No production
M. BOHOL					
23. Guindulman & Anda	New Frontier Mines, Inc.	120,000	20.00% Mn	II	No mining operation
N. ZAMBOANGA DEL SUR					
24. Kumalarang, Picanan	Mercedes P. Sy Egco	6,600	50.00% Mn	III	No production 1981
25. Titay & Tungawan Gabu, Bolihan & Dayat	G. T. Lluch & Son's, Inc.	26,700	34.10% Mn	III	Ceased production 1972
26. Ramon Magsaysay	Philippine Manganese	17,500	48.00% Mn	III	No mining operation
O. AGUSAN DEL NORTE					
27. Cabadbaran, San Antonio	Associated Mining Corp.	17,200	43.50% Mn	III	Operation suspended 1980
ADDITIONAL					
ISABELA					
28. Palanan, Dinapigue	Black Rock Mng. Corp.	20,000	40.50% Mn	III	Stopped production

S U M M A R Y

No. of producing mines:	1	
No. of mines that stopped and/or suspende operation	21	TOTAL ESTIMATED RESERVES: 7,534,520 MT
No. of prospect	6	

PHILIPPINE NICKEL DEPOSITS

LOCATION	OWNER/OPERATOR	ESTIMATED RESERVES Tonnage	:	Grade	ECAFE CLASSIFICATION	STATUS
A. ISABELA						
1. Palanan & San Mariano	New Frontier Mines, Inc. (Under operating contract w/Hillecoll Mine Consultant & Management Corporation)	5,000,000	:	2.00% Ni	III	Under exploration
B. ZAMBALES						
2. Sta Cruz	Global Mng. Resources, Inc.	55,000,000	:	1.75% Ni 17.24% Fe 0.04% Co	III	Under exploration & development
3. Sta Cruz	Acoje Mining Company, Inc.	1,015,500	:	0.47% Ni	III	No production
4. Sta Cruz, Guisguis	Benguet Corporation (Sta Cruz Laterite Nickel Project)	24,000,000	:	1.60% Ni	III	Under exploration '81
C. CAMARINES NORTE & QUEZON						
5. Mt. Kadig	Horizon Mineral & Oil Corp.	83,129,840	:	1.40% Ni 30.00% Fe	III	Geological/ Explored
D. OCCIDENTAL MINDORO						
6. Sablayan	Anglo Philippine Oil Corp.	49,000,000 (laterite)	:	0.94% Ni	III	Geological '70/ No recent report of activity
E. RONBLON						
7. San Fernando, España	Sta Barbara Development Corp.	10,000,000 (laterite)	:	1.50% Ni	III	Under exploration
F. EASTERN SAMAR						
8. Borongan, Hibacong	G. Y. Ormopia & Son's, Inc.	13,278,512	:	0.56% Ni	III	No mining operation

PHILIPPINE NICKEL DEPOSITS

F. EASTERN SAMAR					
9. Guinan, Hanical, Is.	Palawan Syndicated Ventures	7,652,965	: 1.65% Ni 57.61% Fe	III	Under explo-
G. LEYTE					
10. Jaro, Antipolo	Saturn Minerals, Inc.	3,030,000	: 0.23% Ni	III	Evaluated '74/ No recent report of activity
H. SURIGAO DEL NORTE					
11. Dinagat Is., Awasan	Surigao Nickel Reservation	387,712,048	: 0.65% Ni 44.98% Fe 0.09% Co	III	Evaluated '68/ No mining operation
12. Nonoc Island	Marinduque Mining & Ind'l Corp. (Nonoc Nickel Proj.)	203,541,115	: 1.23% Ni 36.174% Fe 0.10% Co	III	Producing
13. Tagana-an, Bo. Talavera	Hinatuan Mining Corporation	1,485,113 (laterite)	: 2.25% Ni 12.80% Fe 0.09% Co	III	Evaluated '80/ Under developmnt
I. SURIGAO DEL SUR					
14. Carrascal, Adlay	P. D. Ago Enterprises	14,000,000	: 0.56% Ni 48.00% Fe	III	Under exploration & development/ Target date of operation is '85 covering three placer claims
J. PALAWAN					
15. Puerto Princesa City, Buenavista	Apollo Oil Expl. & Mineral Development Corp. (Palawan Nickel Project)	10,794,650	: 1.60% Ni	III	Under exploration

PHILIPPINE NICKEL DEPOSITS

J. PALAWAN					
16. Berong, & Long Pt.	West Palawan Cons. Nickel Mines, Inc.	151,000,000 (laterite)	: 1.50% Ni	III	Under exploration/ & development
17. Berong, Long Pt., & Moorsom Pt.	A. Soriano Corporation (Atlas Cons. Mng. & Dev't Corporation)	204,100,000 (laterite)	: 1.55% Ni	III	The development of this laterite deposits depends upon improvement of the world market price for nickel
18. Narra	Trident Mining & Ind'l. Corp.	21,967,000	: 2.00% Ni	III	No mining operation
19. Narra, Pulot	Olympic Mines & Dev't Corp. (Pulot Nickel Project)	2,631,168	: 2.04% Ni 22.25% Fe	III	Evaluated '73/ Under exploration
20. Narra, Bato-Bato	Olympic Mines & Dev't Corp. (Toronto Nickel Project)	3,670,712	: 2.05% Ni 20.69% Fe	III	Under exploration
21. Narra, Calategas	Olympic Mines & Dev't Corp.	1,752,000	: 2.04% Ni 58.00% Fe	III	Under exploratin
22. Brookes Pt., Ipilan	Palawan Nickel Corporation	6,149,457	: 1.75% Ni 28.66% Fe	III	Evaluated '71/ No recent report of activity
23. Brookes Pt., Ipilan	Infanta Mineral & Ind'l Corp. (Ipilan Nickel Project)	2,513,000	: 2.20% Ni 22.25% Fe	III	Operation is under suspension & on care and Maintenance basis
24. Batarasa, Rio Tuba	Rio Tuba Nickel Mng. Corp.	52,865,600	: 2.07% Ni	III	Producing
K. DAVAO ORIENTAL					
25. Pujada	A. Soriano Corporation	220,000,000 (laterite)	: 1.19% Ni	I	No mining operation
26. Mati, Pujada	Apo Bano Metals, Inc.	165,000,000	: 1.25% Ni	III	Under care and maintenance basis

PHILIPPINE NICKEL DEPOSITS

K. DAVAO ORIENTAL

27. Mati, Makambal	LBC and Greenfields Mng. Co.	90,718,582	: 1.00% Ni	III	No mining operation

Total, metric : 1.751 x 10^3 [illegible]

S U M M A R Y

No. of Producing Mines:

No. of Mines that stopped and/or suspended operation:

No. of Prbspects:

TOTAL ESTIMATED RESERVES:

PHILIPPINES
MAJOR METAL RESERVES

(PBMG LISTINGS)

- Chromite
- Nickel
- Copper
- Gold-Silver
- Iron
- Manganese

LIST OF CHROMITE MINES AND PROSPECTS

LOCATION	OWNER/OPERATOR	ESTIMATED RESERVES Tonnage	:	Grade	STATUS
A. BUKIDNON					
1. Impasugong, Ingkalumad	Domingo C. Ortega	60,000 MT	:	52.49 % Cr_2O_3(M)	Stopped Operation
2. Malitbog, San Luis	Valaya and Son's Res. Dev. Corporation	3,000 MT	:	50.00 % Cr_2O_3(M)	Stopped Operation
B. CAMARINES SUR					
1. Lagonoy, Himagtokon	New Frontier Mines, Inc.	18,000 MT	:	44.06 % Cr_2O_3(M)	Stopped Operation
2. Lagonoy, Himagtokon	Cam-Meta Minerals, Inc.	99,900 MT	:	47.00 % Cr_2O_3(M)	Producing
C. DAVAO ORIENTAL					
1. Gov. Generoso, Nangan	Loyalty Mining and Dev. Corp.	145,000 MT	:	46.62 % Cr_2O_3(M)	Stopped Operation
2. Gov. Generoso, Nangan	Davao Timber Corporation	39,724 MT	:	50.00 % Cr_2O_3(M)	Producing
D. EASTERN SAMAR					
1. Gen. McArthur, Llorente and Hernani	Pacific Shore Mining Corp. and Rio Chico Mining Corp.	3,322,889 MT	:	48.00 % Cr_2O_3(M)	Under Exploration Evaluated - 1969
2. Maydulong	Mrs. Concepcion Lastimosa	33,000 MT	:	48.00 % Cr_2O_3(M)	Stopped Operation
E. ISABELA					
1. Divilacan	Island Mining and Ind'l. Corporation	50,700,000 MT	:	48.00 % Cr_2O_3(M)	(?)

LOCATION	OWNER/OPERATOR	ESTIMATED RESERVES Tonnage	Grade	STATUS
F. MISAMIS ORIENTAL				
1. Manticao, Toud	Silver Mines	50,000 MT	48.00 % Cr_2O_3(M)	Stopped Production
2. Sungay, Libertad	Cheston Mining	40,000 MT	48.00 % Cr_2O_3(M)	Stopped Production
3. Opol, Tagsulip	Salvaña - Hojas Estate	60,000 MT	38.43 % Cr_2O_3(R)	No Production - 19
4. Opol & Manticao, Awang	Misamis Exploration Corp.	64,570 MT	10.00 to 48.00 % Cr_2O_3(M)	Producing
5. Opol	Superior Mining and Ind'l. Corporation	57,000 MT	47.00 % Cr_2O_3(M)	Stopped Production
6. Manticao	Apolo Talampas	4,078 MT	48.00 % Cr_2O_3(M)	Producing
7. Alubijid	San Grace Mining Corporation	106,669 MT	48.00 % Cr_2O_3(M)	Producing
G. OCCIDENTAL MINDORO				
1. Looc, Ambil Is.	Mindoro Mineral Enterprises	99,700 MT	33.55 % Cr_2O_3(R)	No Operation
H. PALAWAN				
1. Puerto Princesa City, Irahuan	Palawan Consolidated Mining Co., Incorporated	1,697,000 MT	41.00 % Cr_2O_3(M)	Stopped Operation-1981
2. Puerto Princesa City, Bacungan	Golden Arrow Mining Co., Incorporated	3,664,000 MT	46.00 % Cr_2O_3(M)	Operation Suspended 1980
3. Puerto Princesa City, Irahuan	Liberty Mines, Incorporated	24,000 MT	38.00 % Cr_2O_3(R)	Stopped Operation
4. Narra, Lapu-lapu	Trident Mining and Ind'l. Corporation	16,149,644 MT	25.34 % Cr_2O_3(M)	Producing

LOCATION	OWNER/OPERATOR	ESTIMATED RESERVES Tonnage	Grade	STATUS
H. PALAWAN (CONT'D)				
5. Puerto Princesa City, Aborlan	New Frontier Mines, Inc.	13,000 MT	45.08 % Cr_2O_3(M)	Stopped Operation
6. Narra, Teresa & Bato-Bato	Philippine Chrome Mining Corporation	2,627,498 MT	44.286% Cr_2O_3(M)	Evaluated - 1980
7. Puerto Princesa City, Bacungan	Adams Mining Corporation	6,300 MT	34.00 % Cr_2O_3(M)	No Operation
I. PANGASINAN				
1. Mangatarem, Bunagan	Capitol Mineral Res. & Dev. Co., Inc.	133,386 MT	38.07 % Cr_2O_3(R)	Producing
2. Bunagan	Acoje Mining Company, Inc.	845,000 MT	____ % Cr_2O_3(R)	Under Exploration
J. QUEZON				
4. Municipalities of Baler, San Luis, Aurora, Bos. Bibut, and Cemento	Baler Consolidated Mng., Inc.	20,000 MT	____ % Cr_2O_3(R)	Under Exploration
K. SURIGAO DEL NORTE				
1. Dinagat Island	Malayan Wood Products, Inc.	62,914 MT	48.56 % Cr_2O_3(M)	Producing
2. Libjo, Dinagat Island	Velore Mining Corporation	91,241 MT	48.00 % Cr_2O_3(M)	Producing
3. Dinagat Island	Acoje Mining Compnay, Inc.	4,300,000 MT	____ % Cr_2O_3(M)	Under Exploration and Development
L. SIQUIJOR				
1. Muns. of Maria, Larena & Enrigue Villanueva	New Frontier Mines, Inc.	150,000 MT	48.00 % Cr_2O_3(M)	No Operation

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LOCATION	OWNER/OPERATOR	ESTIMATED RESERVES Tonnage	:	Grade	STATUS
M. ZAMBALES					
1. Candelaria	Inter-Continent Mineral and Oil Corporation	950,000 MT	:	32.00 % Cr_2O_3(R)	Stopped Productior 1980
2. Masinloc, Agop-op	Masinloc Chromite Mining Co., Inc.	53,830 MT	:	35.55 % Cr_2O_3(R)	Stopped Operation
3. Candelaria	A C G Mining and Oil Explo. Corporation	36,341 MT	:	31.40 % Cr_2O_3(R)	Evaluated - 1980
4. Candelaria, Bo. Lawis	Araro Minerals, Incorporated	74,000 MT	:	23.12 % Cr_2O_3(R)	Under Exploration and Development
5. Palauig, Salaza	Philippine Chromite Ores Mining Corporation	466,960 MT 13,270 MT	: :	32.94 % Cr_2O_3(R) 41.37 % Cr_2O_3(M)	Prospect
6. Cabangan, Gahalao	Golden River Mining Corp.	96,000 MT	:	35.00 % Cr_2O_3(R)	Operation Suspende 1980
7. Sta. Cruz	Filipinas Mining Corporation	53,500 MT	:	43.50 % Cr_2O_3(M)	Ceased Operation
8. Sta. Cruz	Zambales Chromite Mining Co.	30,000 MT	:	21.67 % Cr_2O_3(R)	Under Exploration and Development
9. Iba	White Eagle Overseas Oil Co., Incorporated	12,000 MT	:	_____ % Cr_2O_3(R)	
10. Masinloc, Agop-op	Orbit Phil. Consolidated Mines, Incorporated	508,758 MT	:	34.279% Cr_2O_3(R)	Evaluated - 1976
11. Sta. Cruz	Acoje Mining Compnay, Inc.	3,157,992 MT	:	20.00 % Cr_2O_3(M)	Producing
12. San Antonio, Silaguin	Golden Arrow Mining Co., Inc.	69,584 MT	:	16.39 % Cr_2O_3(M)	Operation Suspende 1980

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LOCATION	OWNER/OPERATOR	ESTIMATED RESERVES Tonnage	:	Grade	STATUS
M. ZAMBALES (CONT'D)					
13. San Felipe, Bo. Maloma	Christian Agro-Mining & Development Company	40,000 MT	:	_____ % Cr_2O_3(M)	Under Exploration
		10,721,993		31	
14. Masinloc, Coto	Benguet Corporation	5,310,984 MT	:	32.00 % Cr_2O_3(R)	Producing
15. Sta. Cruz	Armon Mining and Dev. Corp.	720,000 MT	:	20.00 % Cr_2O_3(M)	Under Exploration
16. Palauig, Kinamaligan	Pulsar Mineral Resources, Inc.	396,135 MT	:	28.50 % Cr_2O_3(R)	Producing
N. ZAMBOANGA DEL SUR					
1. Palomoloc, Titay	Mr. Lino Duhaylungsod	1,785 MT	:	46.58 % Cr_2O_3(M)	Stopped Productio 1980

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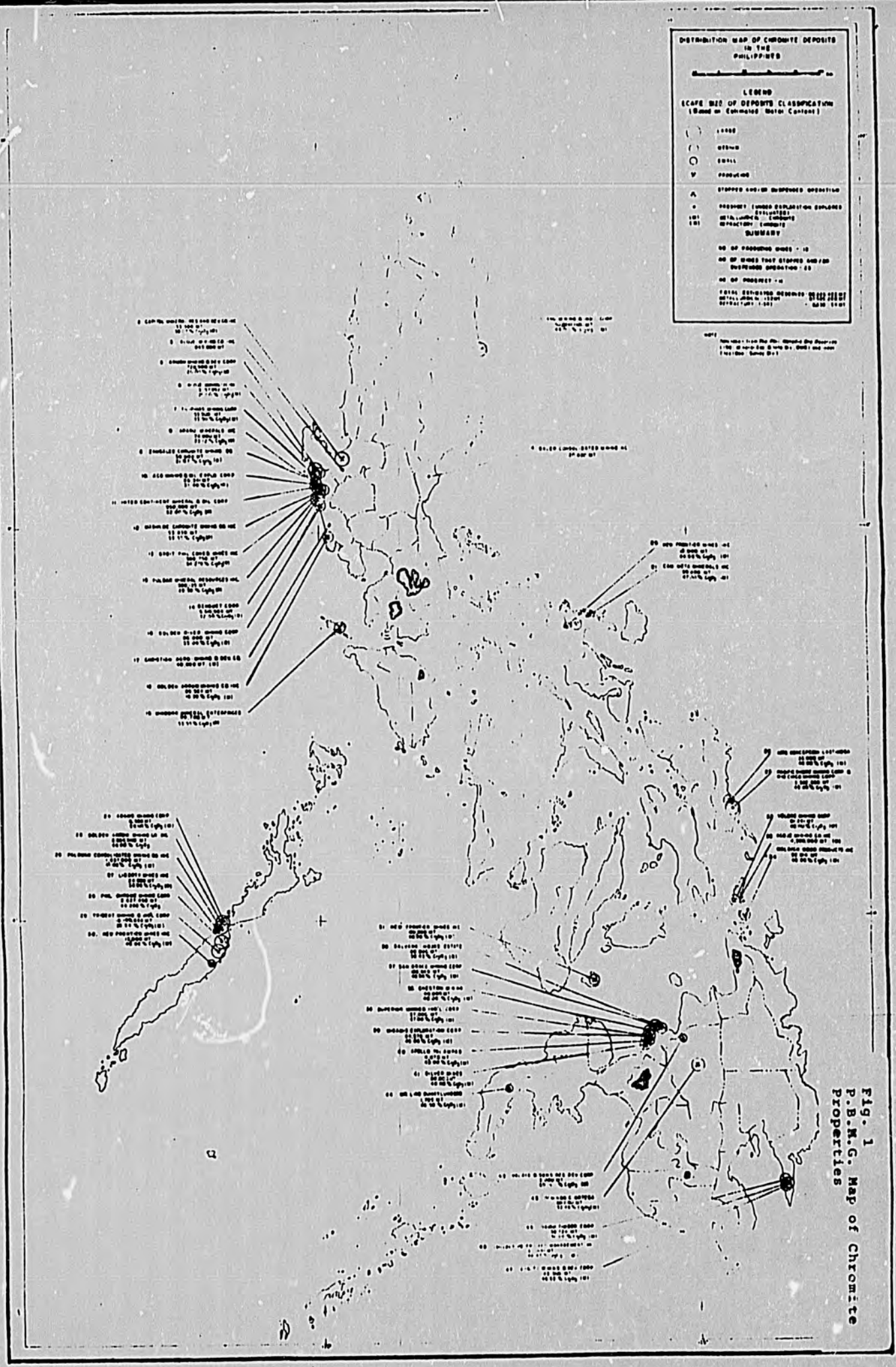


Fig. 1
P.B.M.G. Map of Chromite
Properties

Fig. 2
Philippine Ultramafic Belts;
12 Logistically Favorable
Chromite Exploration Areas

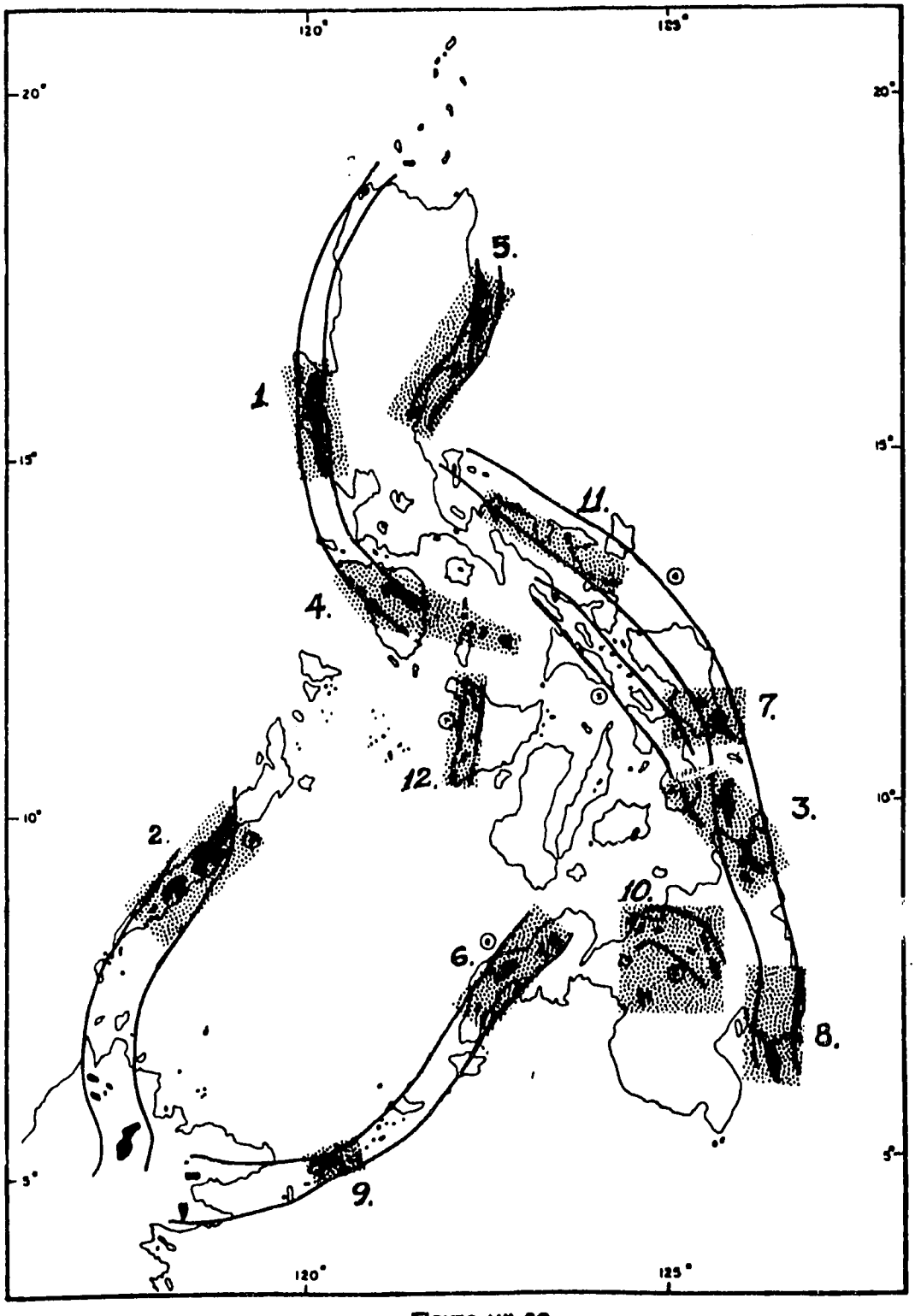
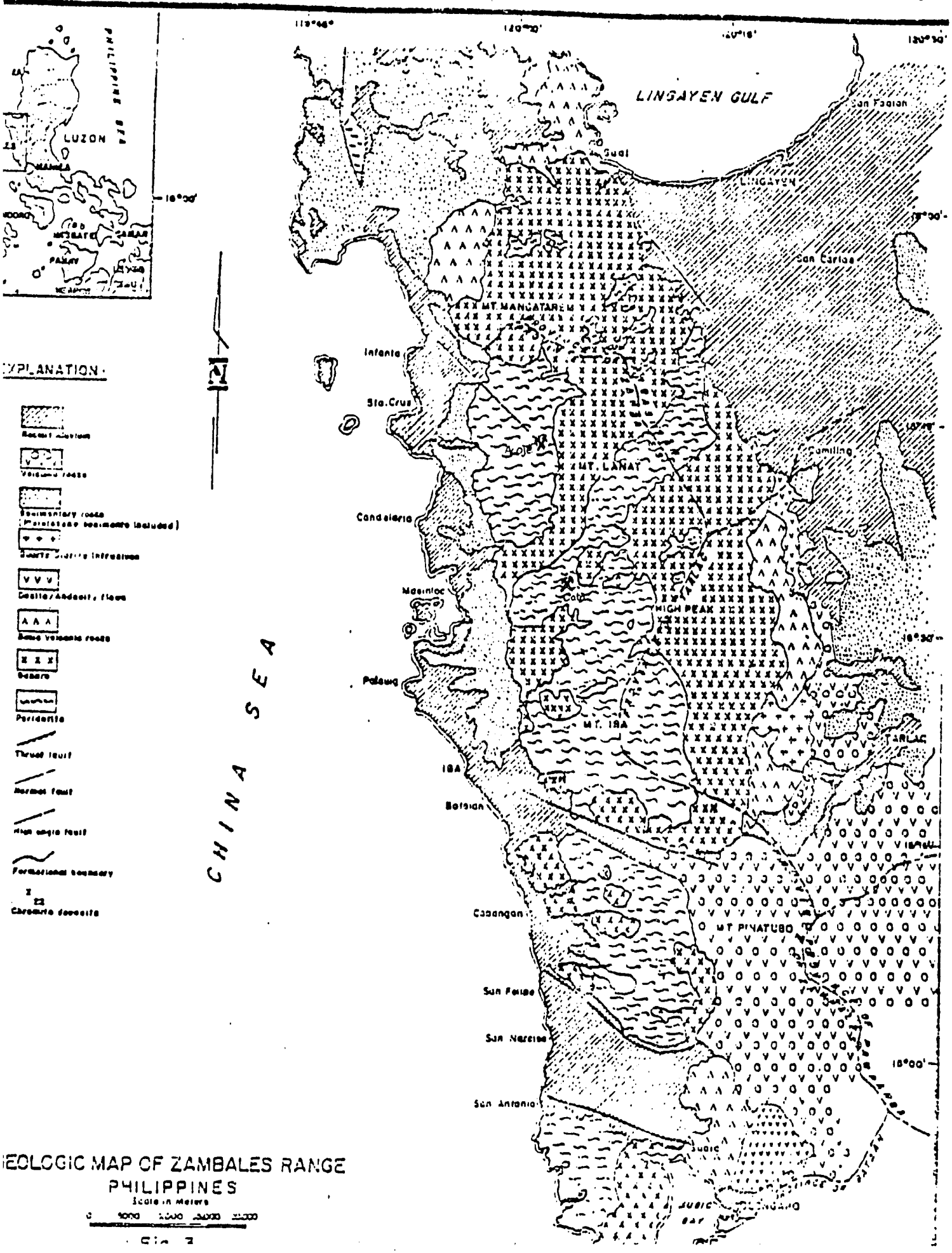


Figure VII-20

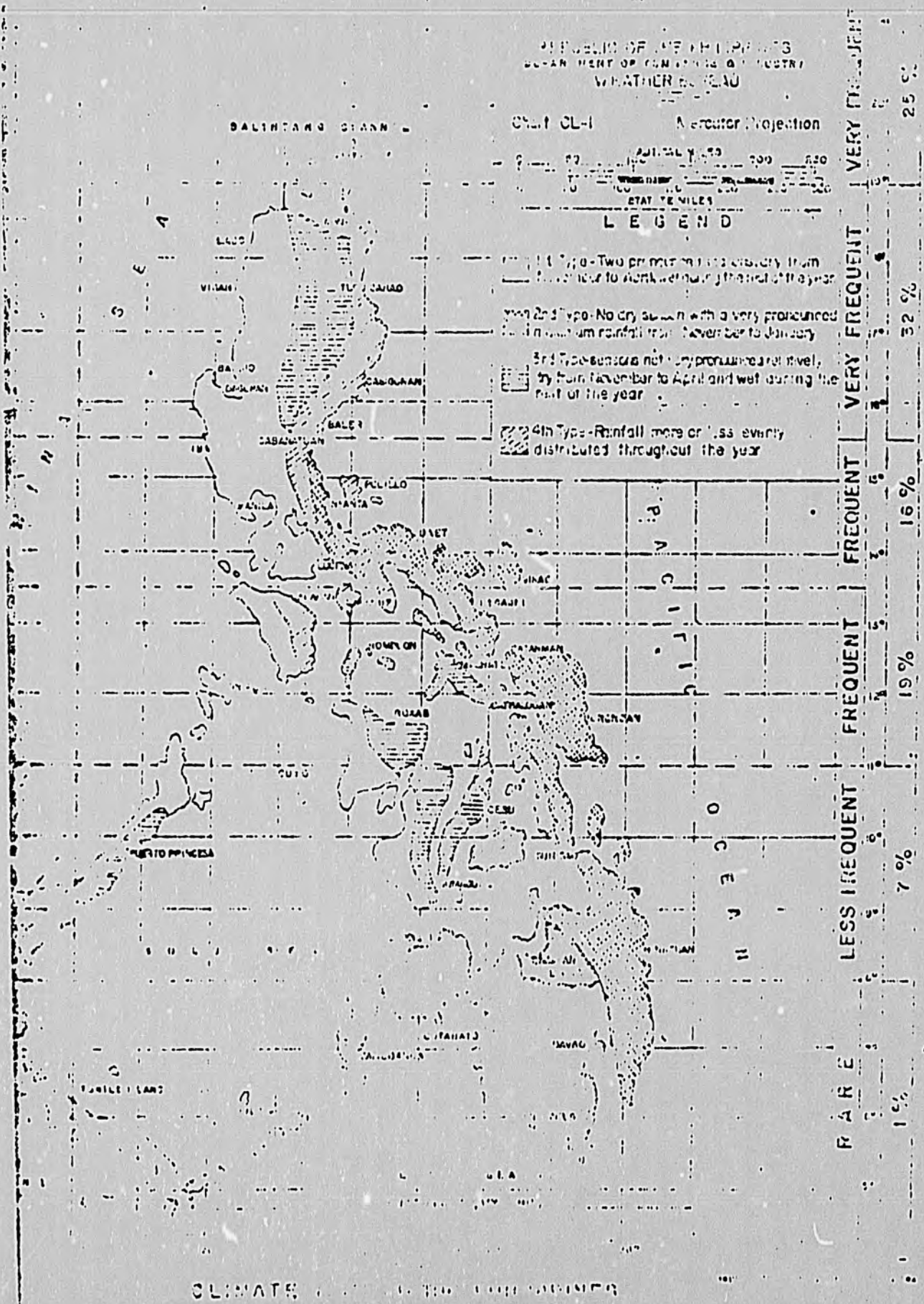
ULTRAMAFIC ROCK OCCURRENCES AND OPHIOLITE BELTS



GEOLOGIC MAP OF ZAMBALES RANGE
PHILIPPINES
Scale in Meters

Fig. 3

Climatic Map



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REPORT

March 10, 1983

Appendix III.

To: Josiah Royce, Project Officer,
U.S. Trade and Development Program
Agency for International Development

Ref: Appropriation Number 72-11X1001

Objective: As a part of the Trade and Development Program's assessment of the potential for chromium production in the Philippines, an evaluation of the metallurgical treatment of the chromite ores was required from a metallurgical consultant.

Scope of Work

The duties of the metallurgical consultant were to include the following:

1. Travel to Honolulu for a 2-day joint consultation with Dr. Charles Johnson at the East-West Center, on a summary of known chromite occurrences in the Pacific-East Asian region.
2. Assess the chemistry and treatment of chromite ores.
3. Examine Philippine ores for presence of deleterious elements and describe methods for eliminating them from concentrates.
4. Make recommendations for changes in metallurgical treatment of ores from mining and milling through the refining process.
5. Analyze cost benefit factors of mining proposals brought to the attention of the TDP mission.
6. Prepare a report to the Project Officer on the findings of the mission.

Chromite Ores - General Features

In the East Asian and Pacific basin ores, the occurrences appear to fall into three general types:

- Chromite hard rock deposits with no other significant metal values
- Chromite in laterites, especially nickel-cobalt laterites
- Chromite in beach, river and stream sands

To date, almost all chromite production has been derived from hard rock deposits of the "podiform" type supplemented with minor production from beach sands.

As a result of exploration of laterites for nickel-cobalt, some interesting occurrences of accessory chromite values have been noted.

According to Dr. Charles Johnson, all New Caledonia laterites, many nickel-bearing, contain some chromite. In addition, there are substantial reserves of chromite in hard rock "podiform" deposits containing high quality chromite.

In New Guinea, the recently explored multi-million ton Ramu deposit is reported to contain about 4% chromite in a nickel-cobalt laterite. This fine-sized chromite can be concentrated to a marketable grade product by using spirals and removing the magnetite. Mixed with wood chips it was satisfactory for charge chrome.

Indonesian nickel laterites such as at Sulawesi also contain blebs of chromite (up to 1/2 inch in size). Occurences were noted in sands ($\pm$ 48 mesh) at lakes and in rivers and on beaches, but no efforts for commercial concentration and recovery have been reported.

For an excellent description of the occurrences of chromite in the Philippines and other Pacific Basin regions, the reader is referred to the paper "Chromite Potential of the Southwest Pacific" by Charles J. Johnson and Jean A. Brady of the Resource Systems Institute; East-West Center, Honolulu.

Specific to the Philippines, at the Acoje Deposit near Santa Cruz current exploration has established good chromite values in the laterite on ridges flanking the presently-producing hard rock mine. Essentially, such chromite is in form of blebs and sandy grains. However, the nickel content of the laterite is only about 0.4%.

An excellent discussion of the occurrence of chromite in Philippine lateritic soils by Gunther Freidrich et al was printed in Erzmetall 33, (1980) Nr. 7/8.

The U.S. Bureau of Mines RI 8676 (1982) entitled "Chromium Recovery from Nickel-Cobalt Laterite and Laterite Leach Residue" by Kirby et al, describes recent test work on four typical U.S. laterites whose chromium contents varied from 1.29% Cr to 1.88% Cr (1.88% Cr_2O_3 to 2.75% Cr_2O_3).

Chromite concentrates assaying up to 22.9% Cr with recoveries of 53% were reported by cyclone desliming and tabling of the granular fraction only.

Of special interest to metallurgists is the extremely fine particle size of the laterite ore samples; approximately 70% by weight averaged only 2 microns and nearly 20% was finer than 1 micron.

The investigation was not successful in producing an acceptable iron ore co-product from the chromite tailings.

Mining and Concentration

Mining of Philippine chromite spans the entire range from "pick and shovel" mines to sophisticated mechanized open pit and underground operations. Although the prime mining targets are high grade lump ores, some disseminated ores are mined and treated.

Obviously, relatively low capital investment is required for producing a saleable product from small, high grade lump ore deposits. The major costs appear to be transportation from the mines to a port (usually over rough mountainous terrain). Low cost labor makes hand sorting economic and the wide difference in specific gravities of chromite (4.2 to 4.9) and the serpentine and ultrabasic gangue rocks (2.4 to 3.5) make for efficient sorting. Even in the large open pit and underground mines, a high grade lump concentrate is economically produced by hand sorting run-of-mine ore.

The chromite ores presently mined in the Philippines can be divided into four major classes from the viewpoint of the metallurgist or beneficiation plant:

1. High grade lumps in the size range of -6" to -8" and + about 1-½".
2. Mixtures of coarse high grade lumps and wall rock diluents from mining.
3. Disseminated low grade ores including laterites.
4. Sand deposits.

Class 1 high grade lump ores obviously require only crushing to the sizes required in the specifications of the buyer.

Class 2 ores require either hand sorting of the + 1½" to 2" and rejection of all finer sized material (the economic limit to hand picking is probably around 1½" particle size) or a combination of hand sorting and gravity concentration of the -1½" fraction. The large mines utilize heavy media (sink-float) methods for upgrading the coarse fractions (-3" +¼") with jigging of the intermediate size fraction (-¼" + 14 mesh) and spiral or shaking table concentration of the -14 mesh fractions.

Class 3 ores may require crushing and grinding (usually in rod mills) to liberation size of the chromite grains from gangue rock. Concentration then is limited to recovery by spirals and shaking tables. To date, no recovery by froth flotation is being practiced.

Class 4 ores do not require grinding but concentration utilizes the same equipment as in Class 3 ores.

Concentration of Chromite

The problems in concentration of chromite ores are remarkably similar to those in the concentration of hematitic iron ores. The processes involve long-proven gravity separations in several size ranges. Magnetic separation does not find application because chromite is only feebly magnetic and only very small amounts of magnetite that might contaminate the concentrates occur as an accessory mineral in the presently-mined deposits.

From flotation of the chromite from gangue minerals using fatty acids or petroleum sulfonates might offer large advantages over tabling but may require extensive research to develop a satisfactory selective process. It must be assumed that to date such a process has not been found because no operation is presently using flotation.

Recovery of chromite from laterites (Class 3 ores) will probably involve intensive scrubbing and desliming steps followed by gravity separation in two or more fine particle size ranges. Impoundment of the tailings slimes becomes very important and large pond volumes are required. However, the numerous uninhabited upper river valleys near the Philippine mines offer opportunities for constructing the required tailings areas.

The ability to mine open pit with virtually no waste stripping and no requirement for grinding, makes this type of mining venture attractive. In addition, if the chromite concentrate is further processed by pelletizing or related agglomeration, the natural fine particle size could be highly advantageous.

There appears to be an abundance of fresh process water for treatment of the chromite ores. Large rivers usually are nearby in the Zambales District and rainfall normally is sufficient to supply processing needs.

Electric power from the north-south National Transmission Grid is available to the two large processing plants that were visited.

Bays and ports are located along the extensive coasts of the Islands, not far from mountain crests.

Impurities

Unlike the problems associated with deleterious elements in iron ores (such as phosphorus, titania, sulfur, base metals and alkalis) the Philippine chromite ores appear to have no such contaminants. Quality control apparently can be gauged simply by silica content - the lower the silica, the higher the chrome - and this becomes the grade index for metallurgical grades. The alumina content (to be as high as

possible compatible with high chrome) is important in qualifying for refractory grade chromites. Magnesia also contributes desirable high melting point characteristics.

Possible Improvements in Processing

Philippine Chromite Ores

Only three chromite ore processing plants were visited in the time allotted for the mission. These were:

1. The small 60-ton per day custom plant of Solid Chrome, Inc. at Gabangan, Zambales
2. The 3500 tons per day concentrator of Benguet Corporation at Coto.
3. The 1500 tons per day concentrator of Acoje Mining Co. at Acoje.

1. Solid Chrome, Inc.

The ingenuity displayed by the manager of the Solid Chrome custom plant was impressive. Small scale equipment had been fabricated largely by local labor or reconstructed from scrapped, obsolete models. The processing included: Jaw crusher, roll crushers, vibrating screens, conveyors, jigs and assorted tanks. All equipment was installed in the open. Crude ore delivery was by small flat bed highway trucks. After classification of the ore as to type and necessary processing, it was handled in lots through the plant.

Each size range, commencing with crushing to about 6" and ending at about 20 mesh, was either hand sorted, jigged or simply washed by sluicing with water

Improvements to the plant would include feed bins, ore feeders, additional jigs, some spiral concentrators and shaking tables, and associated sand pumps. Such equipment would increase throughput, recovery, grades of products and reduce hand labor costs.

2. Coto Processing Plant

The Coto plant provides an excellent example of the technical and operating skills of Philippino labor and management. The plant employed processing equipment that spanned the full size range of from -3" to 200 mesh. Constructed some 35 years ago, it is maintained in spotless condition. Never has the writer observed better housekeeping and cleanliness in even the most modern ore processing plants.

The only suggested improvements were to replace the now obsolete belt-type electro magnetic separators (used for recovery and cleaning of the ferrosilicon heavy media) with modern, more efficient drum-type permanent magnet separators. This would reduce media losses during operation and especially during electric power outages when all media in the belt-type separators is lost. Power consumption would also be lowered.

A second improvement would be to replace the Wemco open-top, internal airlift, cone separation vessel in the - 5/16" to 10 mesh heavy media circuit with a "dynamic" cyclone separator. A more efficient separation of the finest ore particles should result and there should be less lost time when stopping and starting the circuit due to power-outages or maintenance.

It is understood that some testing of an ore sorting process based on treating coarse lumps under reflected light had been completed in Australia but the results were not acceptable.

Figure 1 shows the Coto plant flowsheet with basic process steps and average weight splits by size ranges of products.

3. Acoje Processing Plant

Reference to the Acoje plant flowsheet in Figure 2 shows that the circuit is complex, involving rod milling and multiple-spiral separators with a total of 27 full-sized sand and slime shaking tables. Due to increased throughput, several

processing units are overloaded, and a deficiency in the final concentrate dewatering circuit was obviously having adverse effects on the operation.

A suggested improvement would be to install a mechanically-vibrated "dewaterizer" to remove free water from the rake product of the concentrate dewatering spiral classifier. This would improve performance of the belt weightometers, reduce the moisture content of the final concentrate and avoid losses of "slime" chromite now leaking from the loading bins.

Another possible improvement would be to substitute froth flotation for slime tabling. Suggested reagents would be fatty acids and petroleum sulfonates plus fuel oil. High solids (70%) conditioning of a thoroughly deslimed pulp, either in alkaline or acid circuit should be investigated.

Finally, operating supply costs might be reduced by converting the curved bar screens to uniformly sloping screens, such as is practiced in the Florida phosphate washing plants.

Brief observation indicated that water consumption might be reduced by providing longer retention time of water sprayed on vibrating screens by installing plates or pockets in the screen surfaces.

If further expansions of capacity are undertaken, it would be prudent to evaluate Reichert pinch sluices as a substitute for shaking tables. These devices require small floor space, have no moving parts, and are easy to maintain. However, they are vulnerable to plugging with wood pulp fibers. Protection against this problem is mandatory.

Controlling Sizing of Concentrates

In the case of iron ores, adverse price differentials apply if too large a proportion of the concentrates are below a certain size. The same applies to metallurgical chrome ores. Reduction furnaces perform best when charged with rigidly controlled size ranges of ore, coke and flux. Fines in the charge materials tend to cause

operating problems and high dust loads in off-gases so there usually is a limit on the bottom size of the furnace feed materials, including the ore.

Mining and milling practices usually strive to keep as much material as possible in the coarse ranges and to minimize the production of fines. Aside from market restraints, there are advantages in doing so because (1) fine crushing and grinding are expensive steps and (2) separation efficiencies and machine capacities decrease sharply as the particle size of the feed material decreases. Therefore, it is much to the advantage of the operator to keep the feed as coarse as possible compatible with required mineral liberation.

When ore characteristics demand that fine crushing and grinding be employed, the resulting concentrates may be so fine that agglomeration, sintering or pelletizing may be required before they can be utilized in reduction furnaces.

While such agglomeration is usually a high cost step, it may be the only way to insure marketability for metallurgical purposes. High quality pellets, for example, often benefit the buyer and furnace operator by improving metal output and quality.

It is recommended that metallurgical chrome producers support studies aimed at developing a good pelletizing process which can utilize the finer fractions of the chrome concentrates. It is understood that some work has already been done on briquetting, sintering and high temperature (+3000°F) pellet induration, mostly in overseas laboratories.

An economic pelletizing process may open the door to increased chrome production from the disseminated or "salt and pepper" types of ores and from sands and laterites where little or no mineral is coarser than 48 mesh. For example, it is indicated that substantial tonnages of disseminated chromite ore occur in the Acoje deposit but are below present cut-off grade for underground mining. A technical break-through that would permit inclusion of such type of mineral in ore reserves could materially increase the life of the current operation.

Lateritic Chromite Deposit

Acoje Mining Co., Inc. has begun evaluation of an impressive laterite chromite project which surrounds their underground chromite mining area at Sta. Cruz.

- The laterites occur principally along ridge tops in thicknesses ranging up to 15 feet, with typical thinning on the sloping hillsides.

There are 6 principal areas, four of which have been test pit sampled on a 100-foot grid. The farthest occurrence is about 6 km from the existing plant.

Acoje's March 1980 ore reserve data show the following:

Area	MT * Tonnage	Avg. Grade %	MT ** Tonnage	Avg. Grade %
I	155,000	12.00	180,000	9.00
II	95,000	11.00	106,000	8.50
III	190,000	11.00	236,000	8.60
IV	182,800	12.00	690,300	9.50
V	287,600	10.00	330,600	8.50
VI	19,700	12.00	25,000	8.50
TOTAL	930,100	11.33%	1,567,900	8.76%

* At 8.00% Cr_2O_3 cut-off grade

** At 6.00% Cr_2O_3 cut-off grade

When the cut-off grade is lowered to 4.0% Cr_2O_3, the reserves are more than doubled as indicated below:

Area	MT Tonnage	Avg. Grade %
I	594,300	7.00
II	150,000	6.50
III	541,400	6.80
IV	710,000	7.00
V	1,600,000	6.60
VI	43,000	7.00
TOTAL	3,636,700	6.80%

Considering that open pit mining of the laterite would involve stripping only of surface vegetation, and that virtually no crushing and grinding would be required, there are attractive advantages to a lateritic deposit. Offsetting these advantages to some extent is the difficulty of loading and hauling ore during wet weather, the need for very large slime tailing impoundment areas, and high water consumption. Also, the maximum particle size of the concentrates would probably be less than 20 mesh and much would be finer than 200 mesh.

Chromite Ore and Concentrate Prices

The February 1983 Engineering and Mining Journal lists the following:

> "Chrome ore, dry basis, subject to penalties if guarantees are not met, f.o.b. loading point; term/contracts (subject to negotiation) are generally lower."
>
> Transvaal, mt
> 44% Cr_2O_3, no ratio $51-55
>
> Turkish, mt
> 48% Cr_2O_3, 3 to 1 $110
>
> Russian, mt
> 53-55% Cr_2O_3 4 to 1 ratio
> (pricing basis 48% Cr_2O_3) Suspended

The Philipinas Mineral Industry Magazine for July-Dec. 1982 listed the April-June 1982 values of chrome ore and concentrates as follows:

Product	Quantity - DMT	Phil. * Pesos	U.S. * $
Met. Concentrates	22,758	377.4	39.73
Met. Ore	1,795	488.8	51.45
Refractory Ore	59,584	1027.5	108.16

* All per DMT

Detailed Analysis of Typical Benguet Chrome Ore

As reported by Japanese sources, the analysis of recently-produced Masinloc ore by sized products is as follows:

	Lumpy	+ 10 Mesh	- 10 Mesh	- 100 Mesh	Met. Blend
Ign. Loss	1.29	0.82	0.57	0.08	--
SiO_2	5.99	5.03	4.83	1.90	7.76
Al_2O_3	28.63	28.32	28.21	29.60	26.67
FeO	9.58	10.43	10.87	11.92	12.36
CaO	0.61	0.48	0.49	0.43	--
MgO	---	17.96	17.52	17.52	20.87
Cr_2O_3 *	32.44	33.06	33.07	36.35	29.53
Calc. Fe Cr_2O_4 (Chromite)	42.02	43.09	43.94	48.27	41.89

* Refers to "chrome oxide" - not chromite.

Areas of Possible Interest to U.S. Mining Companies

From a strictly technical point of view and assuming a corporate objective of acquiring a position in the Philippine chromite industry, some suggestions for U.S. mining company participation would include:

1. Installation of a custom chrome ore processing plant which employs the most modern and efficient equipment. Prior to installation, assessment of the regional ore reserves which would support the plant must be completed. This could involve some exploration.
2. Exploration and development of chromite-bearing laterites aimed at production of high value refractory grade chrome concentrates.
3. Exploration and development of chromite-bearing beach and river sand deposits large enough to support an economic operation.

4. Joint venture with a Philippine company in the development of an established chromite-bearing laterite deposit.

5. Joint venture with a Philippine company in expanding production of chromite from an existing operation including both mining and processing.

6. Joint venture with Philippine companies to install and operate an agglomeration or pelletizing plant for metallurgical fines.

7. Joint venture with Philippine companies to install a ferro-chrome plant at a low cost hydro electrical energy source.

8. Installation and operation of a plant for production of refractory chromite bricks in the Philippines.

A major attraction and advantage for the suggested ventures listed above is the low cost and high efficiency of the large skilled labor pool in the Philippines.

Mining companies considering investment in the Philippines must carefully evaluate the legal limitation of not more than 40% foreign ownership of a Philippine mining company.

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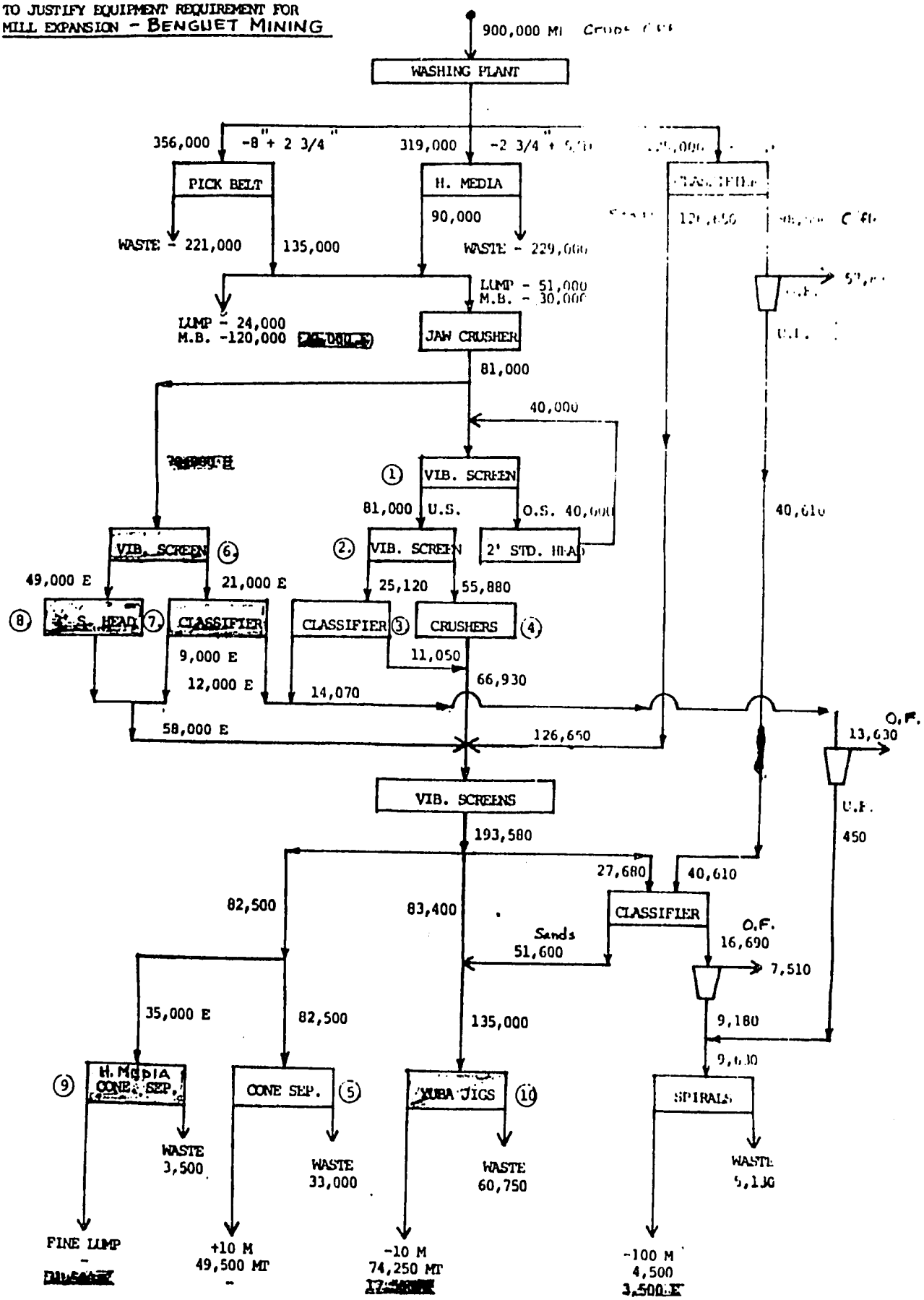
FIGURE 1
COTO CHROMITE PLANT

MATERIAL BALANCE IN SIMPLIFIED FLOWSHEET TO JUSTIFY EQUIPMENT REQUIREMENT FOR MILL EXPANSION - BENGUET MINING



NOTE:

2. "E" denotes materials from crushing 70,000 MT of M.B. but do not include materials from 100,000 MT L.O. new feed to washing plant.

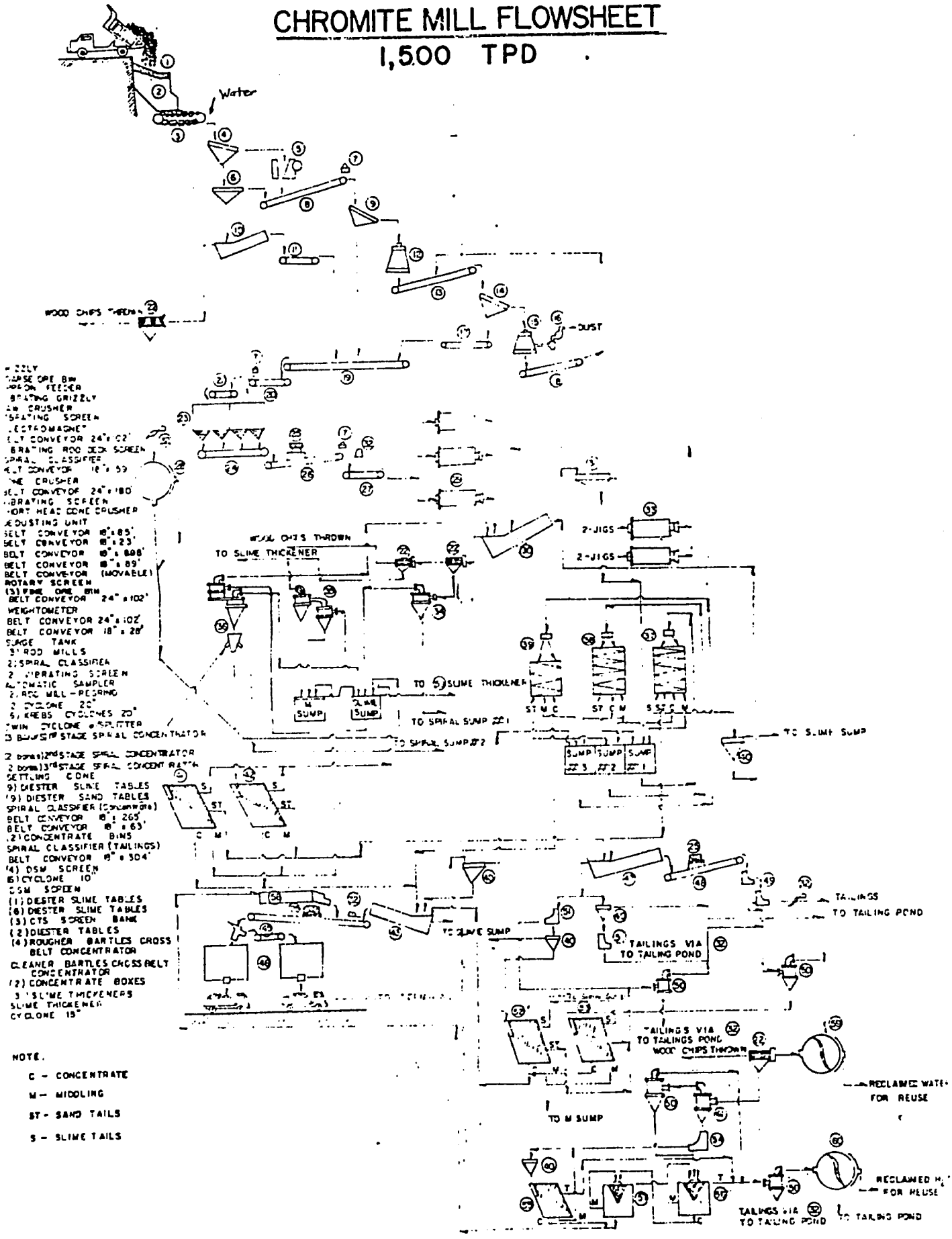
FIGURE 2

ACOJE MINING COMPANY, INC.

STA CRUZ, ZAMBALES

CHROMITE MILL FLOWSHEET

1,500 TPD



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