THE MOLANGO AREA (MEXICO) MANAGANESE DEPOSITS OF COMPANIA MINERA AUTLAN THE LARGEST KNOWN MANGANESE ORE RESERVE IN NORTH AMERICA

JUNE 1983

Prepared by Josiah Royce

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INTRODUCTION:

Manganese ore is essential for the production of virtually all steels, where its desulfurizing, deoxidizing, and inhibition of grain boundary carbide formation are beneficial. In alloy steels and other alloys it imparts toughness, hardness and hardenability. In dry-cell batteries, manganese dioxide is used as a depolarizer in the cell, where it serves as a ready source of oxygen. In addition it has widespread chemical industry applications.

In 1982 the U.S. Bureau of Mines estimates that the U.S. imported 99% of its manganese requirements. Some 700,000 tons of manganese ore (typically 35% to 54% manganese), and 500,000 tons of ferromanganese (ranging from 74% to 95% manganese) were consumed in the U.S. in 1982, containing about 700,000 short tons of manganese metal. This consumption was only 51% of the 1978 figure and indicates the depressed state of the U.S. metals industry in general. In 1980 the European Economic Community also imported 99% of its manganese, and the Japanese 97%, while Russia was an exporter.

Identified reserves of manganese oxide on land total about 1.5 billion tons of contained metal of which the Republic of South Africa has nearly 800 million and the U.S.S.R. nearly 400 million. Thus 80% of these presently known oxide reserves are in potentially unstable or hostile countries.

Reserves (in terms of short tons of manganese metal) are tabulated below for the next ranking countries:

Country	Reserves (Short tons contained Mn metal)
Australia	130,000,000
Gabon	80,000,000
Brazil	43,700,000
India	21,500,000

These nations, while more favorably disposed politically, and from the human rights point of view, are far from U.S. metal refineries and chemical plants.

World manganese ore production for 1981 and estimated production for 1982, exhibit a somewhat parallel relationship.

World Mine Production	Mine Production (thousands of short tons)	
	1981	1982 e/
United States	--	--
Australia	1,554	1,200
Brazil	e/ 2,090	1,700
Gabon	1,640	1,400
India	e/ 1,650	1,400
South Africa, Republic of	5,555	4,400
Other Market Economy Countries	e/ 2,231	1,000
China	e/ 1,760	1,700
U.S.S.R.	10,360	10,400
Other Centrally Planned Economies	146	100
	e/26,000	23,000

Resources (other than reserves) on land total 1.6 billion tons, with the Republic of South Africa and the U.S.S.R. again controlling 86% of this more speculative tonnage.

However the seabed metalliferous nodules are thought to contain 18 billion tons of manganese metal admixed with copper, nickel, and cobalt. Many metallurgists feel that without a sharp increase in manganese prices, recovery of the copper, nickel, and cobalt may be all that is economically possible given the complexity of the mix. At any rate, technical problems in the metallurgy and the means of harvesting these nodules will, when added to the difficulty of obtaining a workable Law of the Sea, set back undersea manganese mining for at least twenty years.

This somewhat precarious supply situation has prompted the U.S. Government to stockpile several types of manganese-bearing materials as shown below:

Stockpile Status--11-30-82 (thousands of short tons)

Material	Goal	Total Inventory	Authorized For Disposal	Sales, 11 Mos.
Battery: Natural ore	62	185	45	-
Synthetic dioxide	25	3	--	-
Chemical ore	170	221	51	-
Metallurgical ore	2,700	2,409	--	-
Ferromanganese: High Carbon	439	600	--	-
Medium carbon	--	29	--	-
Silicomanganese	--	24	--	-
Electrolytic metal	--	14	--	-

In addition to data shown, the stockpile contains 34,000 tons of natura battery ore and 961,000 tons of metallurgical ore, both nonstockpile grade. The foregoing data pertain to uncommitted inventories. The stockpile contains additional quantities of natural battery ore and metallurgical ore, both of stockpile grade, that have been sold but not yet shipped. In October 1982 the General Services Administration (GSA) announced that 25,000 tons of chemical ore was available for sale throu September 30, 1983.

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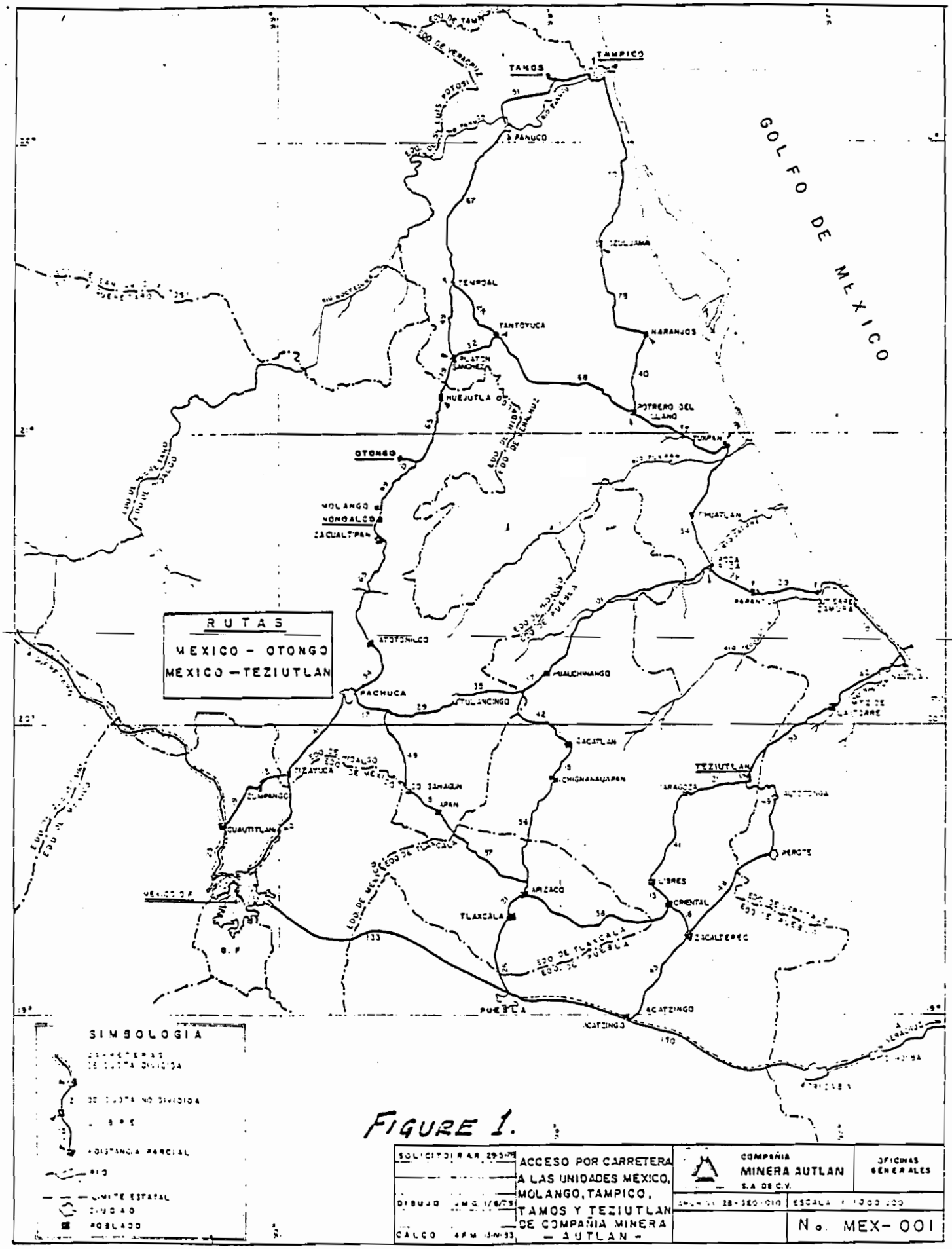

FIGURE 1.

SOLICITO R.A. 29-5-79	ACCESO POR CARRETERA A LAS UNIDADES MEXICO, MOLANGO, TAMPICO, TAMOS Y TEZIUTLAN DE COMPAÑIA MINERA - AUTLAN -	COMPAÑIA MINERA AUTLAN S.A. DE C.V.	OFICINAS GENERALES
DIBUJO J.M.G. 1/6/79		ESCALA 1:1000.000	
CALCO A.F.M. 13-IV-93		No. MEX-001	

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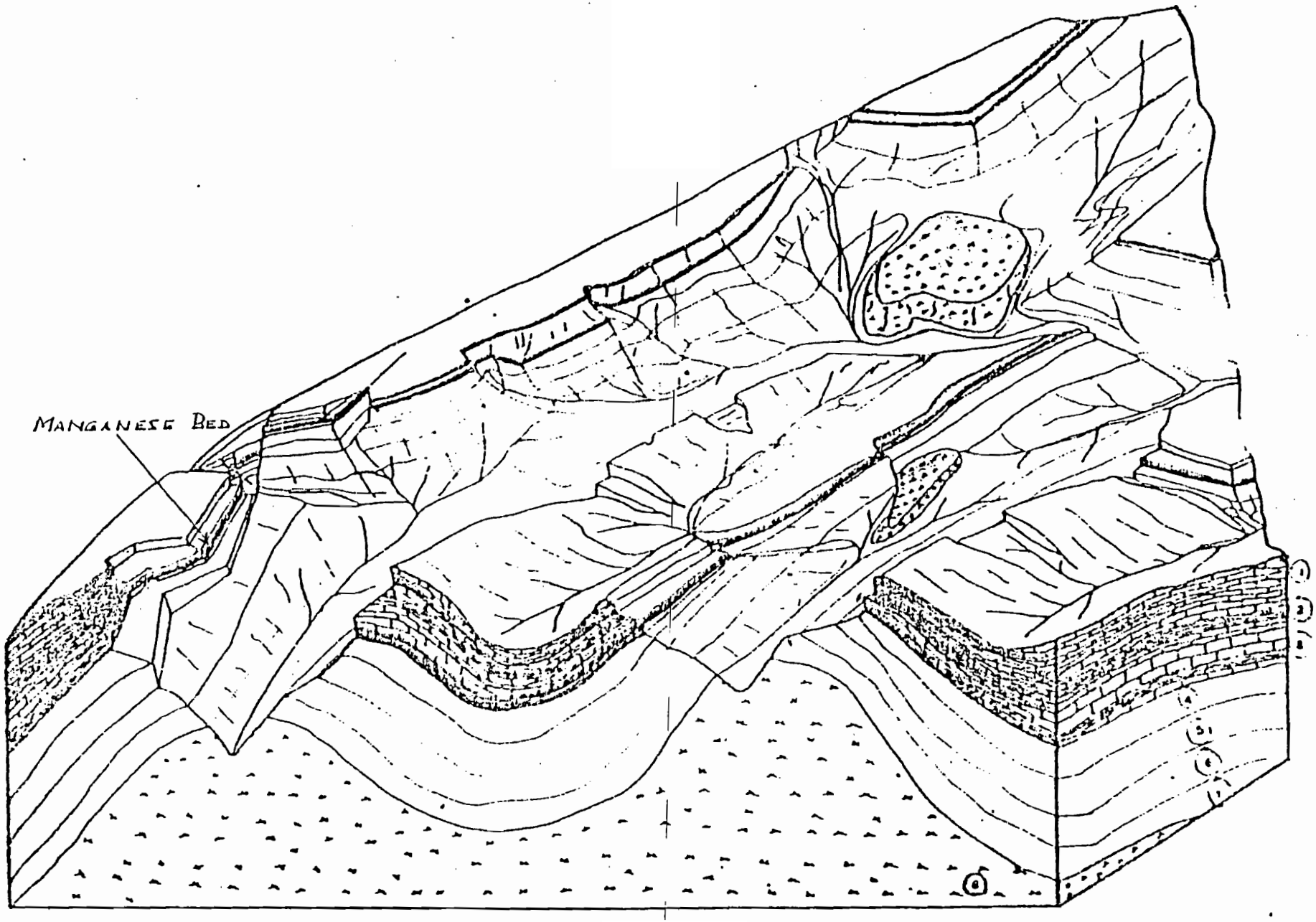

1 RECIENTE
2 PIMIENTA
3 TAMAR
4 CAMUSAS
5 HUATACOCOTLA
6' HUIZACHAL
7 GUACAMAYA
8 PRE-CAMBRICO

FIGURE 2.

DIAGRAMA ISOMETRICO DE LA CONCEPCION DEL PLEGAMIENTO Y EROSION DEL YACIMIENTO MANGANESIFERO DE MOLANGO	COMPAÑIA MINERA AUTLAN S. A. DE C.V.	
	ARCHIVO ING. II	SIN ESCALA
	ENERO 1976	

As part of its program to give new emphasis to strategic minerals and metal-related activities in accordance with its legislative mandate, the Trade and Development Program (TDP) sent a team of three earth scientists to Mexico in the latter half of April, 1983. Since Mexico was reported to have more than a billion tons of manganese carbonate ore on this continent, it was considered prudent to evaluate the economic potential of the Molango manganese deposits of Compania Minera Autlan and assess opportunities for U.S. firms to participate in expanding this foreign source of supply of manganese. The team was composed of the writer as Team Leader, Earl C. Herkenhoff, a distinguished extraction metallurgist and former Vice President Technical Services, Marcona Corporation, and George K. Biemesderfer, former Chief Geologist, Bethlehem Steel Corporation. (Bethlehem, in the late 1960s and early 1970s had an interest in Autlan's operations.)

Compania Minera Autlan - Its History and Its Products:

The "Compania" began mining manganese oxide in 1953 at the village of Autlan, in Jalisco, and exporting its ore through the port of Manzanillo on the Mexican west coast. With the discovery of a large area of manganiferous carbonates (with included oxide pockets) near Molango, Hidalgo, in the Sierra Madre Oriental in 1960, the center of Autlan's operations gravitated eastward.

A mining town, complete with schools, church, living facilities and all necessary infrastructure, was built near Otongo (See Figure 1) 257 kilometers north of Mexico City on National Highway 105, a hard-surfaced two-lane road.

Otongo is approximately at the center of the manganiferous zone containing more than 180 square kilometers of ground, large parts of which are underlain by manganiferous carbonate rock. It is 260 kilometers by road from the Port of Tampico which exports Autlan's products. Near Otongo folded Jurassic limestones (See Figures 2 and 3) and siltstones include the Chipoco manganiferous carbonate formation, a fine-grained, compact, dark gray rock 150 meters thick. Only the bottom few meters of the Chipoco are rich enough in manganese to be classified as ore now. Autlan geologists estimate that there are about 15 billion tons of carbonate rock averaging 10% manganese, of which only some 1.5 billion tons analyze 25% manganese, and from this a measured economic reserve totalling 28.4 million tons of carbonate has been explored in detail in several separate ore bodies. In addition, near Nonoalco,

TABLA DE CORRELACION ESTRATIGRAFICA

ERA	PERIODO	EPOCA	EDAD	AREA MOLANGO	HUAYACOCOTLA	ZACATLAN	TEHUACAN
CENOZOICO	CUATERNARIO	RECIENTE					ALUVION, ARENAS Y CENIZAS VOLCANICAS ROCAS IGNEAS EXTRUSIVAS
		PLEISTOCENO					
	TERCIARIO	PLIOCENO	ASTIANO PLAISANCIANO	VOLCANICAS	VOLCANICAS	ALUVION TUXPAN	
		MIOCENO	PONTIANO SARMATIANO TORTONIANO HELVETIANO BURDIGALIANO AQUITANIANO			COATZINTLA ESCOLIN	TEHUACAN
		OLIGOCENO	CHATTIANO RUPELIANO TONGRIANO			PALMA REAL MORCONES	
		EOCENO	LUDIANO BARTONIANO AUVERSIANO LUTETIANO CUISIANO YPRESIANO			CHAPOPOTE TANTOYUCA CHICONTEPEC SUP. – GUAYABAL	GRUPO SALSAS
		PALEOCENO	TANETIANO MONTIANO DANIANO			CHICONTEPEC INFERIOR MEDIO VELAZCO BASAL	
MESOZOICO	CRETACICO	SUPERIOR	MAESTRICHTIANO SENONIANO: CAMPANIANO, SANTONIANO, CONIACIANO TURONIANO			MENDEZ SAN FELIPE AGUA NUEVA	MEXCALA SN. FELIPE NECOXTLA GUCMANTLA
		MEDIO	CENOMANIANO ALBIANO			TAMAULIPAS INFERIOR	TAMAULIPAS SUP. ORIZABA
		INFERIOR	APTIANO MEDIO CRETACICO: BARREMIANO, HAUTERIVIANO, VALANGINIANO, BERRACIANO		TAMAULIPAS INF.	OTATES	OTATES SAN JUAN RAYA TAMAULIPAS INF. TLACOYALCO
	JURASICO		TITHONIANO	PIMIENTA	PIMIENTA	PIMIENTA	PIMIENTA
		SUPERIOR	KIMMERIDGIANO: BONONIANO, HOVRIANO, SEQUANIANO	CHIPOCO	TAMAN	TAMAN	TAMAN
			OXFORDIANO: ARGOVIANO, DIVESIANO	SANTIAGO	SANTIAGO	SANTIAGO	SANTIAGO
			CALLOVIANO	TEPEXIC	TEPEXIC		TEPEXIC
		MEDIO	BATHONIANO BAJOCIANO	CAHUASAS	CAHUASAS		TENEXCATE
		INFERIOR	LIASICO: AALENIANO, TOARCIANO, CHARMUTIANO, PLIENSBAQUIANO, SINEMUTIANO, HETTANGIANO	HUAYACOCOTLA	HUAYACOCOTLA		HUAYACOCOTLA
	TRIASICO	SUPERIOR	RETIANO NORIANO CARNIANO	HUIZACHAL	HUIZACHAL	HUIZACHAL	HUIZACHAL
		MEDIO	LADINIANO ANICIANO				
		INFERIOR	SCYTIANO				
PALEOZOICO	PERMICO			GUACAMAYA		ROCA METAMORFICA ESQUISTOS	MATZITZI
	PENSILVANICO						COMPLEJO METAMORFICO
	MISISIPICO						
	DEVONICO						
	SILURICO						
	ORDOVICICO						
	CAMBRICO						
	PRECAMBRICO			BASAMENTO			BASAMENTO

Ausente por erosion o hiatus

Contacto inferior no observado

COMPAÑIA MINERA AUTLAN S.A. de C.V.

CORRELACION ESTRATIGRAFICA

FIGURE 3.

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weathering has removed the calcium carbonate fraction of the ore zone and oxidized the manganese carbonates, resulting in small enriched manganese oxide deposits, which can be beneficiated to battery grade ore by washing and gravity separation.

Near Nonoalco these soft oxide ores are divided into four categories the best of which, type A, analyses more than 30% manganese, and about 9.5% iron in the ground. After beneficiation, it is shipped at 48.9% manganese and 6.8% iron.

The more ubiquitous carbonate ores average about 25.7% manganese in the ground utilizing a 20% manganese cutoff. Run-of-mine carbonate ore is crushed, washed, sized, and dewatered. Following this, portions of it are fed to a 375' long kiln at Otongo which drives off the carbon dioxide and creates nodules of merchantable black manganese oxide analyzing:

Manganese	39.1%	(107 cu. meters of natural gas is consumed per metric ton of nodules)
Iron	8.0%	
Silica	14.3%	
Alumina	3.25%	
Ca O	10.00%	
Mg O	4.33%	
Sulfur	0.37%	

Autlan maintains a large geolocial staff who have systematically trenched, channel sampled, and diamond drilled the various deposits at intervals as close as 50 meters.

Their results represent measured economic reserves, and are tabulated below:

Location	Type	Reserve (Metric tons)
Tetzintla	Carbonate	15,000,000
Comextetintla	Carbonate	2,000,000
Acoxcatlan	Carbonate	3,400,000
Naopa	Carbonate	8,000,000
Total Carbonate		28,400,000
Nonoalco	Oxide	900,000

About 18 square kilometers have been intensely explored over the years and 180 square kilometers remain. Thus the above reserves can be vastly expanded by further exploration if a market can be demonstrated. For a more detailed account of Molango geology, please refer to Biemesderfer's report attached as Appendix I.

The Tetzintla mine is located in an area of high relief in the sierra Madre Oriental near Otongo. The No. I operation is an open pit and Mine No. 2 is developed by sublevel caving. The open pit produces 1500 metric tons per day on 8 meter benches with an 6 to 1 (volume) stripping ratio. The underground mine has been developed as a sublevel caving operation using Wagner, EIMCO, and Michigan load-haul-dumpers for tramming.

The Noapa ore body, completely drilled up, is still in the planning stages. It will be an open pit with initial stripping of two years at 1.5 million cubic meters per year. Planned production rate will be 300,000 metric tons per year with overall stripping at a ratio of 9 to 1. Estimated initial capital requirement is $20 million.

Another planned project is the installation of a second rotary kiln needed to nodulize any increased carbonate ore production. Yet another project involves finding and equipping a 1200 gallon-per-minute water supply for the Nonoalco area.

All these development projects await improvement in the managanese market and/or the intervention of a U.S. joint venture partner with available capital.

Transportation Facilities:

Nodules, assaying 39.10% manganese, from the Otongo area, are hauled, by 30 ton Autlan tractor-trailer units, and 10 to 15 end-dump trucks under contract, to the Autlan stockpiling and ship-loading facility at the Mexican Gulf coast port of Tampico. This installation has a stockpile capacity of 75,000 metric tons of which 60,000 can be handled by a combination slewing stacker-reclaimer which is rail mounted at the center of the dock area. Front-end loaders can handle the remainder of the stockpile which is initially loaded into 28,500 dwt. ships at a rate of 1500 tons per hour. (This rate declines somewhat as the stacker reaches further out on the pile.) There is 33 feet of water alongside Autlan's floating 500' dock, and 38 to 40 feet in the access channel.

ELECTRIC SMELTING:

The Tamos electric smelting unit is located beside a 230,00 volt electric power transmission line 20 kilometers west of Tampico adjacent to a railway spur and a paved highway. Here two plants, one a two-furnace Japanese plant commissioned in 1974, and one German two-furnace plant finished in 1977, make high and medium carbon ferromanganese, silicomanganese, and ferrosilicon.

PLANNED 1983 PRODUCTION

Planned 1983 Production:	(Metric Tons)
A. High carbon ferromanganese	101,000
B. Medium Carbon ferromanganese	22,000
C. Silicomanganese	17,500
D. Ferrosilicon	10,500
Total	151,000

The electric furnaces use paste electrodes over one meter in diameter using electric power at 160 volts and 88,000 amperes. We were told that electricity from the national grid is obtained at about 1-1/2 cents per kilowatt hour. Furnace gases are cleaned and burned ensuring that gases vented are relatively clean.

It is noteworthy that Autlan is initiating production of low silica (0.2% Si) Fe Mn products whereas U.S. specs allow up to 1.5% Si. There are no objectional percentages of alkali, phosphorus, or arsenic. The plants employ a total of 590 people, 132 salaried, and 458 unionized laborers. The production rate was given as 20 tons per person per month.

In addition Autlan has silico manganese producing plants in Mobile, Alabama and Peurto Ordaz, Venezuela. For a more detailed account of Autlan's beneficiation and refining, see Herkenhoff's report attached as Appendix II.

Besides the Autlan Group, the team visited the American Embassy, where Darrel Dudley briefed the team leader on Mexican mining and the Mexican Chamber of Mines, where Lic. Eduardo Gonzalez Guerrier, Manager, and Lic. Jaime Mercado, Economist, further described the mining climate in Mexico. A copy of Mexico's Mining Regulation (in Spanish) is available for examination at TDP. Highlights of the discussions are set forth below:

1. Joint mining ventures are permitted with the non-Mexican firm owning up to 49% of the shares.

2. Whereas manganese is open to development by joint ventures with U.S. private sector firms, not all Mexican minerals enjoy the same freedom. A general classification of availability is given below:

a) Petroleum, natural gas, and uranium can only be developed by Mexican government-owned organizations.

b) For coal, iron ore, phosphate, potash, and sulfur, development preference is given to state-owned companies, but some Mexican private sector participation is permitted. Foreign operators are excluded, except for one sulfur producing operation in which Texas Gulf is reported to have a 34% interest.

c) Other minerals and metals are considered available to U.S. joint venture enterprise, but any U.S. firm contemplating entry into joint mining ventures in Mexico is advised to check the appropriate regulations in force on arrival in Mexico.

3. A potential problem area is repatriation of foreign exchange earnings, profits etc., obtained as a result of Mexican mining operations. This can be done in full but we were informed that all foreign currency generated must be promptly deposited in a Mexican Bank. The Bank then gives dollars(or whatever foreign exchange is involved) to the foreign mining group at an artificial rate somewhat below the Bank rate due to an administrative lag behind inflation. At the time of the visit repatriation was at 103 pesos to the dollar, while the bank rate hovered near 150 pesos to the dollar. Adjustments will probably be made, but perhaps not rapidly enough, or often enough.

In summary Compania Minera Autlan is an able, well-run Mexican company mining and refining manganese from immense low to medium grade reserves in a country having reasonable mining codes and a long mineral history. Although they are rumored to have incurred a loss in 1982, this could be due to depressed markets; it is certainly not due to lack of reserves.

Conclusions:

Possible manganese interventions by U.S. mining firms in Mexico are:

1. A joint venture with Autlan to open the Noapa deposit and install a second kiln.

2. A joint venture to expand refinery capacity either at Tampico or in the U.S.

3. A joint venture to upgrade Molango carbonate ores by flotation to premium grade. (This would require location and provision of increased amounts of process water.) This venture, if successful, could make Autlan's products richer and thus more competitive in world markets.

4. Some other alternative dictated by the special circumstances of the U.S. firm.

If a U.S. mining firm desires large reserves of manganese in North America, Molango is where they are, and, as Mexico needs foreign capital, this might be the time to act.

Frank W. Royce

APPENDIX I.

MANGANESE DEPOSITS

OF

COMPANIA MINERA AUTLAN

HIDALGO, MEXICO

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High carbon ferromanganese	100,000 Metric Tons
Medium carbon ferromanganese	22,000 Metric Tons
Silicomanganese	17,500 Metric Tons
Ferrosilicon	10,500 Metric Tons

The TDP group visited the Molango deposits during April 24 - 27, 1983. The group leader was Josiah Royce, Coordinator for the U.S. TDP, assisted by Earl C. Herkenhoff, Consulting Mining and Metallurgical Engineer, and George K. Biemesderfer, Consulting Geologist and author of this report.

George K. Biemesderfer

PURPOSE OF THE VISIT

The objective of the visit to Mexico, as cited in the work contract, was to ".... assess the potential for manganese production in Mexico in order to determine what role, if any, there may be for U.S. private sector....".

Since Compania Minera Autlan is Mexico's major producer of manganese ores and smelted manganese products, the scope of the visit was limited to an examination of the Autlan mineral deposits and mines in order to verify the level of measured reserves claimed for the deposits and to gauge the magnitude of the company's total identified resources.

The present-day economics of the mining operation were not studied so the raw material rescurces are not here classified on the basis of present profitability of extraction and beneficiation. In the strict definition of the term, to be an economic reserve, "profitable extraction or production under defined investment assumption" are required. Compania Minera Autlan reportedly operated at a loss in 1982 which theoretically could change the status of the resources classified as "economic". For this reason this report concerns only the measured and inferred tonnages of the resources, their chemical and physical characteristics and their geological locations.

SUMMARY AND CONCLUSIONS

As a result of a four day visit to the Compania Minera Autlan manganese mines and after lengthy discussion with their technical personnel, it is clear that the Molango district provides a major resource of manganese in a location strategically favorable to the U.S.

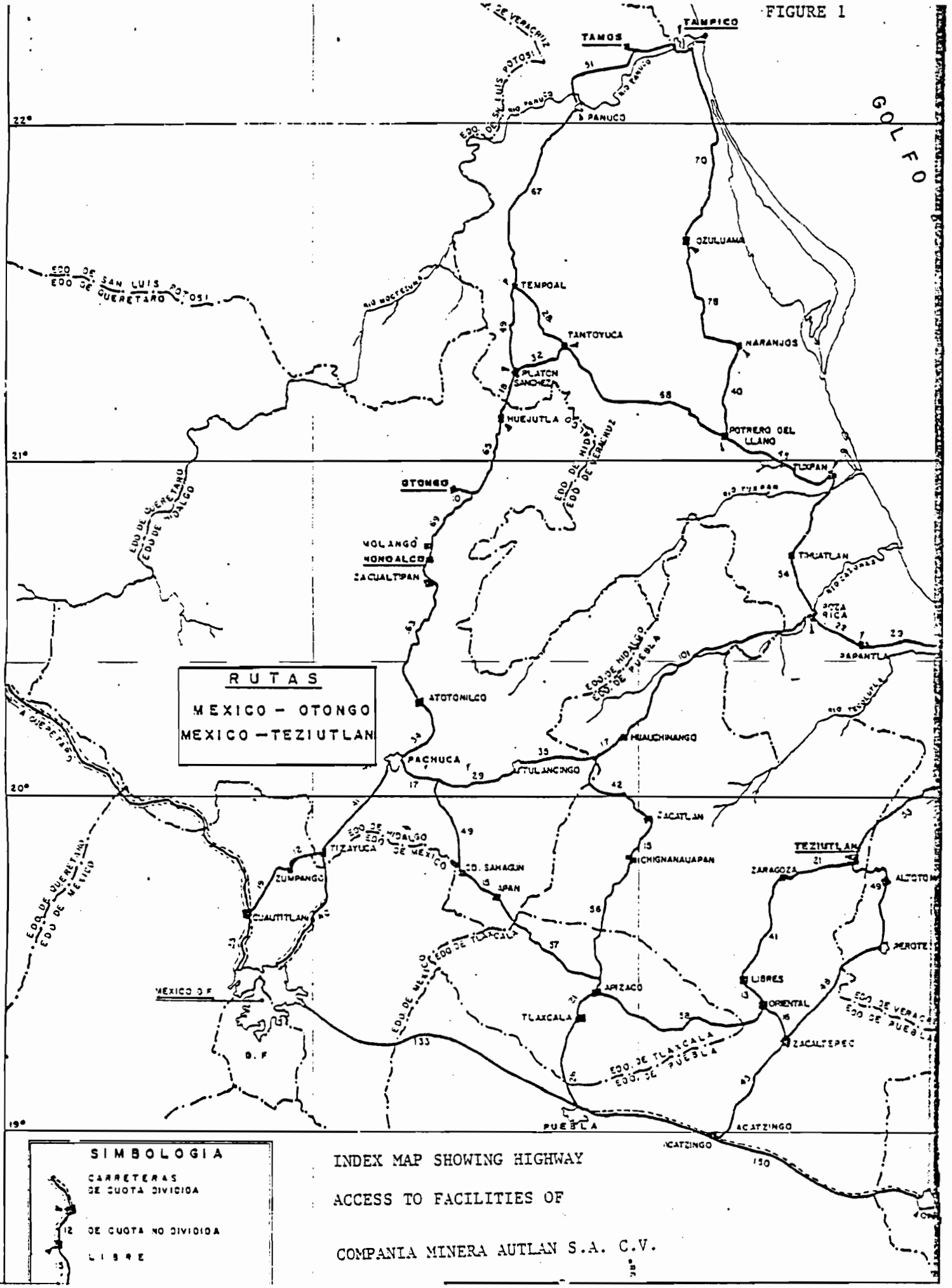
Four deposits in the district contain a measured reserve of 28.4 million metric tons of carbonate rock averaging 27.5% Mn. Mine production is blended then calcined in a rotary kiln to a nodular product containing 40% Mn. This product is marketed internationally through a company-owned port at Tampico and/or smelted to ferromanganese and silicomanganese at the company plant at Tamos near Tampico. Other smelters are located at Teziutlan in Pueblo State and at Mobile, Alabama.

Total identified resources in the Molango district have been given as 15 billion tons of carbonate rock averaging 10%Mn, within which there could be 1.5 billion tons containing +25%Mn. The company also estimates a measured reserve of almost one million metric tons of battery grade oxide ores. The determination of these reserves has been done with competent professional guidance and the tonnages and analyses can be accepted with a high degree of confidence.

It should be noted that the tonnages given are for crude in-situ rock. No allowances have been made for losses in mining or in beneficiation process recoveries.

In regard to the role of the U.S. private sector in Mexican manganese production, the present slump in world steel production and Mexico's general financial crisis are undoubtedly major deterrents to many U.S. investors. However, for a company that may be looking for a secure source of manganese in North America and/or for a supplier with infrastructure, mining, processing, and smelting technologies well established, Minera Autlan could well provide these attributes.

FIGURE 1



INDEX MAP SHOWING HIGHWAY ACCESS TO FACILITIES OF COMPANIA MINERA AUTLAN S.A. C.V.

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LOCATION AND ACCESS

Compania Minera Autlan operates manganese oxide mines at the village of Nonoalco and manganese carbonate mines in the vicinity of the company-built camp of Otongo; both of which are in the State of Hidalgo. The district is known as Molango since the first exploration work was based in a village of that name.

Nonoalco is 178 kilometers North of Mexico City and Otongo is another 79 kilometers further North - the entire route being on hard-surfaced highway. (See Figure 1). The road as far as Pachuca is on fairly level or only gently rolling terrain, but from Pachuca north the road crosses the Sierra Madre Oriental which is a deeply dissected mountain range with steep slopes and relief up to 1600 meters. The road has numerous curves and steep grades so that driving time to Nonoalco in a passenger vehicle was 4 hours.

Mine products are hauled in 20 ton trucks over a hard surfaced highway from Otongo to Tampico, a distance of 260 kilometers. The topographic relief becomes much less severe near Huejutla which places the greater portion of the haul to the port over the Coastal Plain. Generally, a truck makes one round trip per day.

GEOLOGY

Manganese bearing limestones occur in a sequence of Upper Jurassic marine sediments that have been folded into a broad anticlinorium. The northwest plunge of this structure, which is parallel to the trend of the Sierra Madre Oriental, limits the northern outcrop of the mineral zone. The southern end of the belt is covered by Tertiary volcanic rocks which mantled the post-Jurassic erosion surface. The total area of outcrop that has been mapped and investigated by Minera Autlan comprised a zone 50 kilometers North-South by 20 kilometers East-West.

While the regional structure is an anticlinorium, in detail the included subsidiary structures are, at places, extremely complicated with thrust faulting, overturning, and recumbent folding. (See Figure 2)

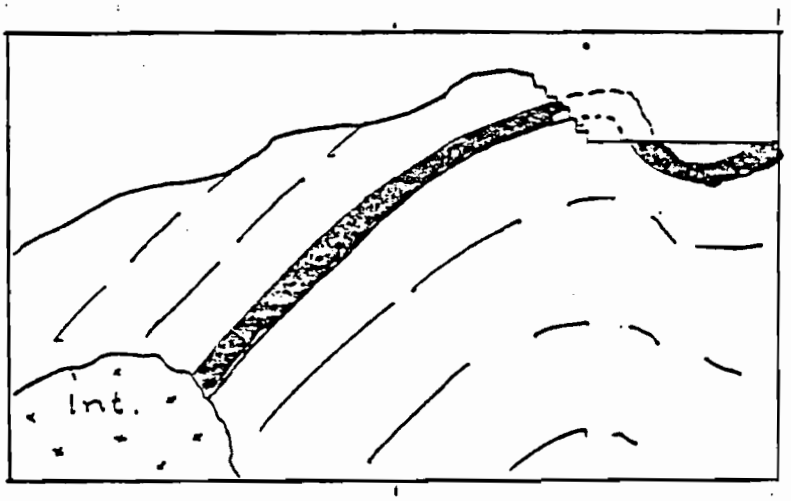
The manganese bearing limestone beds, the Chipoco formation, lie directly above a persistent siltstone, the Santiago formation, that forms a readily identifiable marker bed and in most places a sound footwall for mine development. (See Figure 3). The higher values of manganese generally occur in the beds just above the footwall contact; lower amounts vary through the upper part of the section. The thickness of manganese bearing unit is about 150 meters but only the lower 30 to 50 meters contain manganese values ranging from 1 to 30% manganese.

These rocks are extremely fine grained, dense and compact. They are dark gray in color, and aside from the higher density of the better grade manganese bearing rocks, the could be overlooked as ordinary limestones.

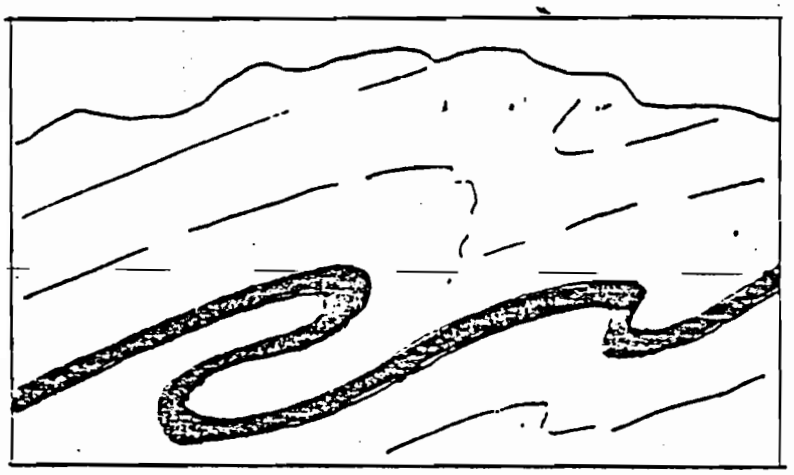
Mineral constituents of the parent rock are rhodochrosite, kutnahorite, calcite, quartz, pyrite, and organic carbonaceous material. A report on X-ray diffractionstudies gave the relationship of the three carbonate minerals:

1. Calcite ($CaCO_3$) as part of the rock ground mass and in cross

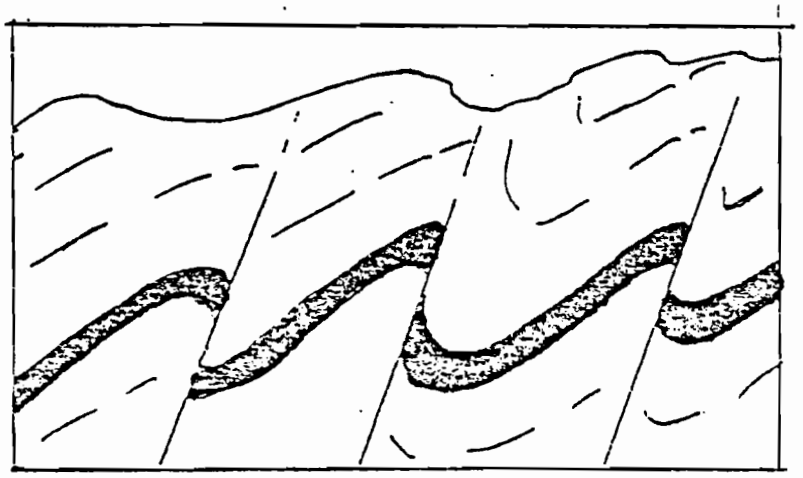
TYPES OF GEOLOGIC STRUCTURES



SW North End of Tetzintla NE



SW South End of Tetzintla NE



Naopa

(No Scale)

cutting veins. The ground mass calcite probably contains appreciable Mn^{++} in solid solution. It might be designated maganoan calcite.

2. Kutnahorite $[CaMn(CO_3)_2]$ occurs as part of the crystalline ground mass.

3. Rhodochrosite ($MnCO_3$) also is part of the crystalline ground mass but may contain appreciable Ca^{++} which would permit the designation calcian rhodochrosite.

Secondary pink rhodochrosite occurs in veins and as fault breccia matrix.

The carbonates are believed to be chemical precipitates that were deposited in response to varying conditions of oxidation-reduction potential, pH, and ion concentration in the Jurassic Sea. Reducing conditions probably produced the iron content as pyrite and also dropped some of the carbonaceous material. The quartz and clay mineral appeared to be detrital.

At places, as in the Nonoalco region, the Chipoco formation has been leached and oxidized for variable distances both up and down-dip from the outcrop. Removal of the calcium carbonate portion of the rock plus oxidation of the manganese has resulted in local but rich bodies of battery grade manganese that can be beneficiated by washing and gravity separation.

Minerals found in these deposits are: nsutite, psilomelane, cryptomelane, birnesite, hausmanite, limonite, clays and quartz.

EXPLORATION

Exploration has been carried out continuously in the Molango area since 1963 when mapping and sampling of the Chipoco formation was begun. This first work which involved channel sampling on 500 meter centers resulted in the discovery of several zones where mineable thicknesses of the limestones averaged 25-27% Mn. One of these, an area known as Acoxcatlan, was diamond drilled first, and when 8 million tons of 27% Mn rock had been proven, plans were made to develop an underground mine.

In 1967, exploration adits driven into the Acoxcatlan outcrop revealed faulted structures too complicated to be mined at reasonable costs so attention was shifted to the Tetzintla area where thin overburden on the crest of an anticline offered more profitablt possibilities as an open pit operation. This mine still produces 58% of the feed to the Otongo plant and the down-dip portion to Tetzintla has been developed as an underground mine to produce the remainder of the plant feed.

Exploration continues at the operating properties both as a means of maintaining a measured 20 year reserve and as quality control.

A staff of 10 geologists and geological assistants service both the Molango and Nonoalco units.

Regional work continues from both mining camps to fill in details of previous work. About 53 kilometers of outcrop are being channel sampled on 100 meter centers and five Longyear diamond drills produce about 8,000 meters of core every year from surface drilling in select target areas. According to the exploration manager, the area North of Tetzintla that remains to be explored is about 100 times the size of the area now known or about 180 square kilometers.

The Naopa deposit was diamond drilled on 50 meter centers to outline a structurally complicated body containing 8 million metric tons. This project required a full year to drill 7,000 meters.

Autlan's core drilling is done with only water as drilling fluid and core recovery has been generally excellent in the carbonate deposits and the battery grade material. Drilling machine availability has been over 80%.

The Acoxcatlan area is being re-evaluated and the eastern side of Acoxcatlan is being explored in detail. The manganiferous beds are 21 meters thick in this area but the higher grades are found in the bottom 1.5 meters.

RESERVES

Minera Autlan categorizes their most certainly identified tonnages of economic resources as "proven reserves" and with that classification the following figures were presented:

Location	Type	1,000 Metric Tons
Tetzintla	Carbonate	15,000
Comextetintla	Carbonate	2,000
Acoxcatlan	Carbonate	3,400
Naopa	Carbonate	8,000
Total Carbonate		28,400
Nonoalco	Oxide	900

These carbonate reserves were calculated to average 27.5% Mn with a 20% Mn cutoff. Reserve tonnages are increased each year in accordance with the production rate to maintain a 20 year supply.

Outside of these closely drilled and well known areas a wide variety of resource tonnages and catagories could be estimated depending upon what Mn grade may become profitable to produce in the future. For instance, a global figure of 15 billion tons of 10% Mn has been estimated as a hypothetical resource for the entire area. Within this global estimate 1.5 billion tons of +25% Mn have been also estimated as another hypothetical resource.

These figures are for in-situ rock only. No dilution or losses due to mining have been included nor any reduction factor for losses in beneficiation.

MINING

The Tetzintla open pit mine continues to provide carbonate feed to the rotary kiln nodule plant. Mine benches are carried at 8 meters high with an 8:1 stripping ratio (volume basis) and overall mine slopes are 55° to 60°. Daily production of about 1500 tons is trucked 9 kilometers to the blending piles at the kiln.

The underground Tetzintla mine has been developed as a sublevel caving system with entry from the open pit. Two main haulages have been driven, one at the 1,000 meter level which is 3 kilometers long, and a somewhat shorter drift on the 900 meter level. Sublevel drift openings are 4.5 meters by 3.5 meters and are 12 meters apart vertically. A 2 meter pillar is left between sublevel drifts. Long hole fan drilling reaches a maximum length of 20 meters and 1.5 meter cuts are taken as the mine retreats along the strike. Only occasional problems with arch pressures have been encountered as the cave follows the retreat closely.

Wagner, Eimco and Michigan load-haul-dumpers and low profile trucks tram the broken rock to ore passes that have been drilled with a Robbins 71 raise borer. The Robbins machine now has a 6 foot cutting head but will be equipped with a 3 meter cutter to drill a production shaft for the deeper parts of the Tetzintla deposit.

The geologic structure on the northern end of Tetzintla consists of the crest of an anticline and the steep western limb of the fold. (See Figure 2). Toward the South the folding becomes complex to the point of resembling recumbent nappe structures.

In order to guide mining, the geology group filled in the 100 meter sections drilled from the surface with underground diamond drilling on 20

meter section spacing. As a final close control every cut is photographed and channel sampled. The preferred ore zone is marked by the geologist to guide the succeeding cut, then if too much dilution occurs, the rock is passed to a small heavy media plant to remove waste prior to being sent to the kiln area.

The average true thickness of manganese-bearing beds at Tetzintla is 7 meters but only 3 meters thickness is generally taken as the richest part of the formation.

Grade control is important not only from the standpoint of holding the iron content below 8% in the nodule to meet market specifications but also the magnesia, alumina and silica content must be controlled for optimum kiln operation. These substances are responsible for the "ringing" problems near the firing end of the kiln.

Tetzintla ores contain an average of 27.5% Mn, 5.6% Fe, 10% combined Al_2O_3+SiO_2, 5.9% CaO, 8% MgO, and 27%CO_2.

Analyses of all mine samples and exploration samples are made in a well equipped laboratory at Otongo where wet methods, X-ray fluorescence and atomic absorption equipment are used.

At Nonoalco, the soft outcrops of the battery grade manganese oxides are mined in open pits. Four classes of ore are recognized, the best of which is "A" ore containing +38% Mn, 9.5% Fe, 57.4% MnO_2. and 93% peroxide. The washing and jig plant which has 1,000 tpd capacity produces a marketable concentrate of +50% Mn.

The maximum economic stripping ratio at these pits is 5:1. Unoxidized stripping waste is stockpiled for future use as nodule feed.

Four projects are being studied for possible increased future production:

(1) A production shaft some 300 meters deep will be raise-bored at the Tetzintla mine to reduce the haulage length through the deeper levels.

(2) The Naopa deposit with its 8 million metric tons has been

designed as an open pit mine by Dames & Moore to reach an ultimate depth of 200 maters. Plans called for an initial 2 years stripping program at the rate of 1.5 million cubic meters per year. Mine production is to be 300,000 tons per year with an overall strip ratio of 9 cubic meters to 1 cubic meter. Slopes were designed for 50° to 60°. The initial capital requirement for this project was estimated at 3 billion pesos.

(3) The installation of a second rotary kiln had been studied but with the present market demands this project has been postponed. The opening of Naopa had hinged on the construction of the second kiln, so it too has been postponed.

(4) An increased water supply at Nonoalco is required to improve the recovery time from the concentrator. A hydrologist is studying the area to try to provide a 1200 gallon per minute supply.

The completion of these projects will depend on the improvement of the world manganese market and the profitability of the Autlan Company.

SOURCES OF INFORMATION

Principal Contacts at Compania Minera Autlan were:

Lizardo Galvan G., Assistant General Manager

Eugenio Tavera Amezcua, Manager, Geology and Exploration

Roberto Diaz Flores, Manager, Mining

Arturo Bastida Martinez, General Manager, Molango Unit

Jose Manuel Perogordo Oliva, Chief Geologist

Alejandro Cabrera, Manager, Nonoalco Unit

At the Mexico Chamber of Mines a meeting was held with:

Eduardo Gonzalez Guerrier, Manager

Jaime Mercado, Economist

Literature consulted included the following:

1. National Materials Advisory Board, National Academy of Sciences, Publication NMAB-374, 1981, "Manganese Reserves and Resources of the World and Their Industrial Implications"

2. USGS Circular 831, 1980, "Principles of a Resource/Reserve Classification"

3. Clavillo T., Manuel, E&M.J. Nov. 1980, "Autlan"

4. Rentschler, J.S., and Erickson, Jr., E.S., Homer Research Laboratory, Bethlehem Steel Corporation, August 1964, "Mineralogical Examination and Chemical Analysis of Twenty-nine Hand Specimens from the Acoscatlan South Drift and Raise"

The company has been long established and ranks as a major mining and electric smelting ferro-alloy company in Mexico.

The geology and mineralogy of the deposits is being covered in detail by another consultant. However, treatiment of the ores is dependent on the type of minerals present and the Autlan ores can be divided into two classes from that viewpoint:

I. The oxides of manganese found in the southern part of the zone near Nonoalso. "Battery grade" manganese products are derived here from oxidized primary manganese carbonate minerals.

II. The manganese carbonates occurring in the Upper Jurassic Limestone formation which extends over an outcrop length of over 50 km on a near North-South strike.

From the oxide ores, concentrates assaying from 48 to 50% Mn (71 to 74% MnO_2) are produced by washing, scrubbing and jigging. The highest grade carbonate ore found in the district is about 32% Mn. Because of the ultra-fine grain size and close association with the calcium carbonates in the limestones, it is not possible to concentrate the manganese carbonates into rich $MnCO_3$ products. Beneficiation by sink-float (Heavy Media) can select the richer bands of manganese carbonates from leaner material and thus produce a feed to the calcining or nodulizing kiln, but this upgrading is at -4" plus ¼" particle size.

The principal manganese carbonate-bearing portion of the limestones is in the lower 6 to 8 meters of the basal 40 meter thick section. Upper beds can contain from 6% to 8% Mn but are not considered as ore grade. Associated with the manganese is some iron, 4% to 5%, also as carbonates. As the manganese decreases, the calcium carbonate content increases.

Typical manganese carbonate ore being fed to the nodulizing kiln can be described as nearly black in color, dense, hard,

nearly homogeneous in texture, exhibiting semi-conchoidal fracture planes and sometimes containing thin bands of pyrite. Close inspection reveals extremely thin wavy bands of lighter colored calcite-rich material intimately associated with the darker carbonates. (This texture resembles that of some Mesabi magnetic taconites).

Near surface exposures of the carbonate often exhibit slicken sides and manganese oxide coatings on fractures. However, there is little or no clay gouge or primary fines present.

Microscopic studies conducted by Bethlehem Steel and others show that the manganese carbonate is so closely associated with calcium carbonate that separation and concentration would have to depend on (1) extremely fine grinding and probably (2) selective flotation of manganese-rich particles from calcium-rich particles. Obviously, this would be a costly and difficult to control process which requires large quantities of process water.

There is only slight color difference between the manganese-rich beds and the lower grade beds so this precludes hand sorting or use of optical ore sorting devices. Gravity difference apparently is the only practical means to concentrate the manganese-rich portions of the limestone beds at this time.

Aside from the slight sulfur content of the carbonate ores (due to pyrite in the high manganese beds), most of which is driven off as SO_2 during nodulizing, there are no deleterious elements in the Autlan ores. Phosphorus in the nodules is 0.064% and arsenic 0.018%. The high CaO plus MgO imparts desirable self fluxing qualities.

Typical of many mining ventures, Minera Autlan commenced operation in 1962 - 1967 mining from 20,000 to 40,000 TPY of manganese oxides. When sufficient carbonate reserves had been proven, mining began in 1967 and the nodulizing kiln started operation in 1968. Proven reserves presently stand at 27.2 million tons averaging about 27.5% Mn. At Naopa, an 8 million

ton orebody is the intended site for a new mine and second nodulizing kiln, with projected startup in 1985.

Minera Autlan stated that if the average grade of carbonate ore could be lowered to say, 25% Mn, the reserves would be increased 4 to 5 times. Obviously, however, this would require improved beneficiation techniques if present final product specifications are to be maintained.

Present capacity of Minera Autlan is 530,000 TPY but due to the downturn in the steel industry, operations have been curtailed to conform to market demands. Approximately 70% of the ore is now mined underground and 30% by open pits.

I. Nonoalco Unit

The southern portion of the Autlan holdings is located at Nonoalco in rugged terrain at elevations ranging from 1200 to 1800 meters. Open pits have been developed in the westward dipping outcrops of the manganese-bearing limestones where oxidation has converted the manganese carbonates to oxides and by leaching away the finely disseminated calcium carbonates. In the principal open pits, the dip of the beds is 20° to 30° and the thickness of the mined beds is about 30 meters. Highest strip ratio is about 5 to 1.0.

The oxidized ores have about 20% porosity and due to special peroxide qualities, are marketed as battery grade manganese concentrates which bring attractive price premiums and justify treatment of low manganese content crude ores.

The Nonoalco crude ores contain principally nautite, psilomelane, criptomelane and limonite. Considerable clay is associated with the ores and must be removed by washing and scrubbing.

Reserves now stand at 1,400,000 tons of ore which will yield 900,000 tons of total products.

Nonoalco Ores

Type	% Mn	% Fe	% MnO_2	% Peroxide
A	39	9.5	57.4	93
B	35	13.0	51.5	--
C	28	14.5	42.7	92
D	25	11.0	42.7	90

Nonoalco Concentrates

Type	%Mn	% Fe	% MnO_2	% Peroxide
N-4	50.2	7.0	75.0	94.5
N-2	47.5	8.0	71.0	94.5

Nonoalco Plant

All Nonoalco ores are beneficiated in a washing-jigging plant located near the open pits on a sloping hillside. Process water is obtained from a small stream which flows eastward across the manganese-bearing formation, and is in limited supply. There are two tailings basins and water is reclaimed from each.

There are two processing circuits located side by side and the flow sheets are shown in Figures 1 and 2. Circuit No. 2 reprocesses jig tailings following hammer mill crushing to -¼". (The Denver jigs now are by-passed).

The capacity of the circuits is about 1000 MT per day. Manganese recovery averages 85%, with principal losses in the primary classifier overflow. It is planned to install a pump and cyclone on the primary classifier overflow and to treat the cyclone underflow sands on tables and spirals.

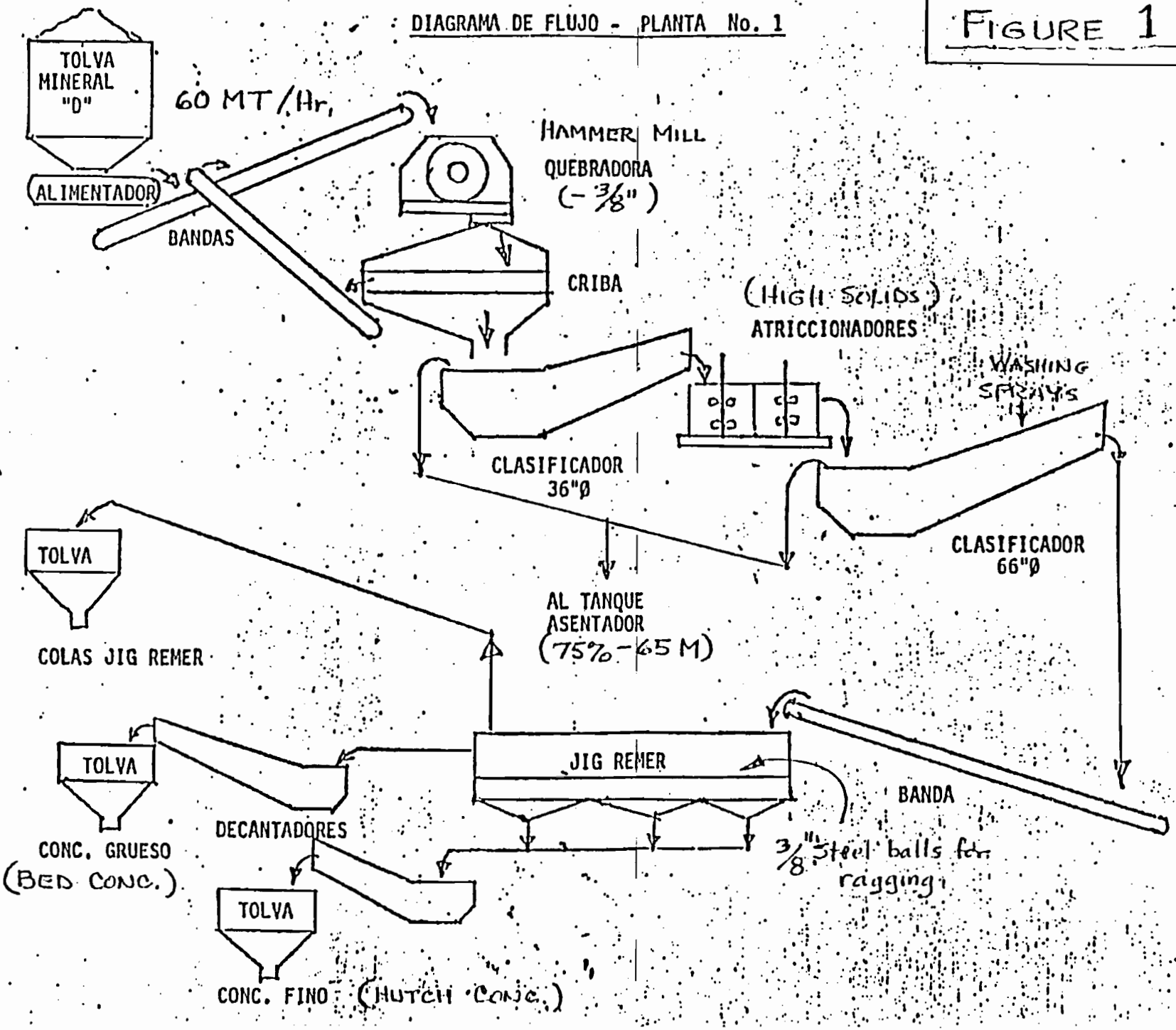
Presently the jig tailings assay around 37% Mn and they are being stockpiled for possible future treatment. Water consumption is 1800 gpm with 15% fresh water makeup.

Froth flotation of the primary fines and reground coarse tailings offers possibilities for higher manganese recoveries and is being considered, but possible effects of reagents on the use of the concentrates for battery purposes may preclude application of flotation.

UNIDAD NONOALCO

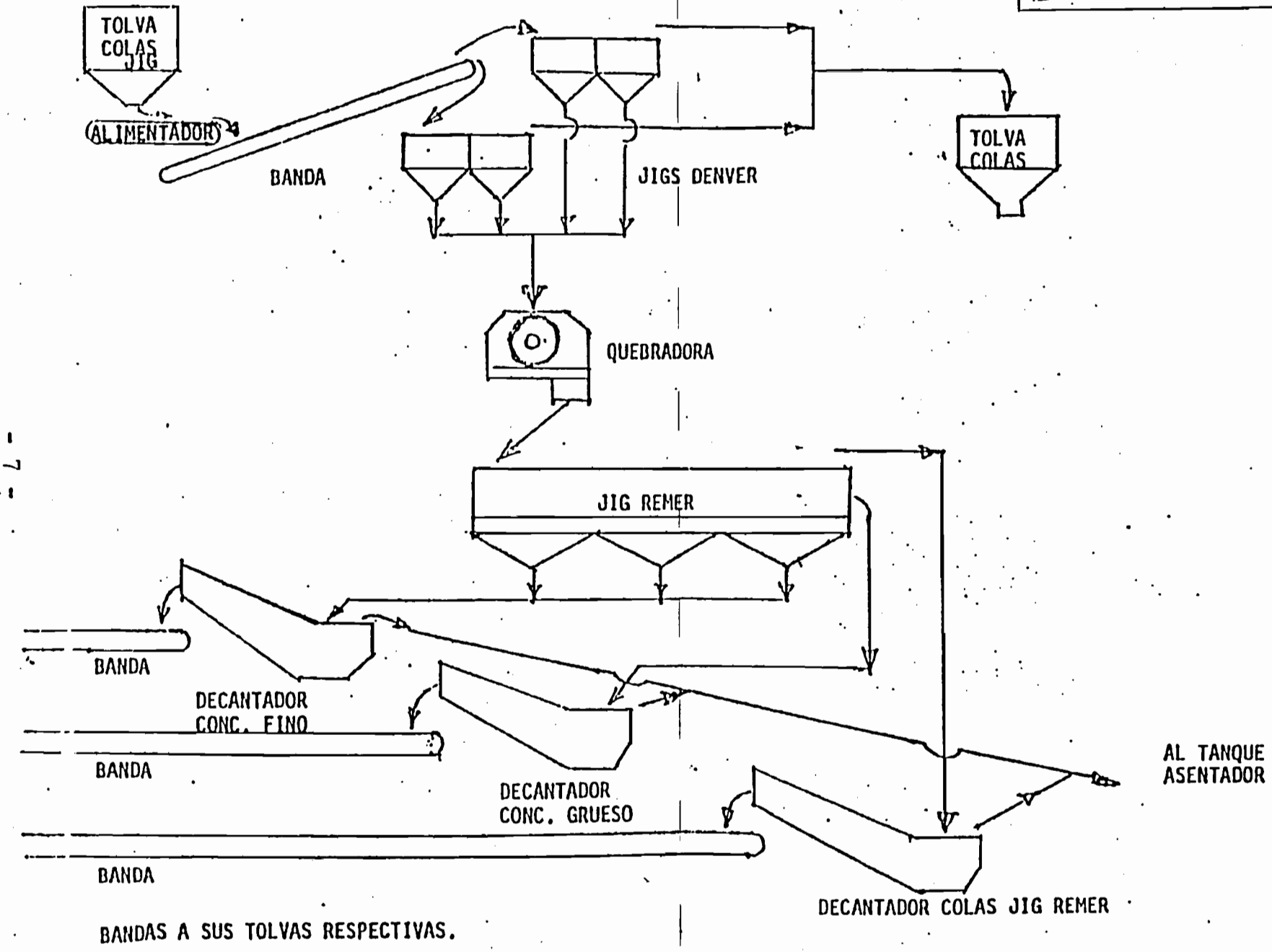
DIAGRAMA DE FLUJO - PLANTA No. 1

FIGURE 1



UNIDAD NONOALCO
DIAGRAMA DE FLUJO - PLANTA No. 2

FIGURE 2



All oncentrates are stockpiled and drained before being trucked to market over existing State black-top highway No. 105.

II. Molango Unit - Tetzintla Mine

This unit incorporates the principal manganese mining operation of Minera Autlan and includes both open pit and underground mines as well as the nodulizing kiln. The company townsite of Otongo is located nearby. The largest reserves of manganese carbonate ores occur here.

As in the Nonoalco district the topography is rugged with steep cliffs, and many slopes are at the angle of repose. Access to the townsite and facilities is by a 10-km private road off State Highway 105. The elevation is somewhat lower than at Nonoalco.

As a result of localized folding and faulting of the manganese-bearing limestone strata, the richer, ore grade portions may be mined by both open pit and underground methods. Where the ore beds have been exposed to surface leaching, some oxidation has taken place but no oxide ores are produced.

Tetzintlan No. 2 mine is now developed to a depth of 900 meters with current underground operations at 600 to 700 meters below surface. Stoping is currently off a 4.5 by 3.0 meter decline using trackless equipment and sub-level caving methods. The minimum thickness of high manganese carbonate beds that can be mined is 3 meters. The ground stands well and can be opened up to a maximum width of 13 meters. Split-set roof bolts aid in ground support. For deeper operations, a 3-meter diameter vertical shaft will be drilled to a depth of 300 meters for the first stage and to 600 meters depth later. Ores derived from the mining operation are either direct feed to the nodulizing kiln, or feed to the Heavy Media plant from which a concentrate suitable for nodulizing is produced.

The Acoxtlan Mine has reserves of 1.5 million tons of carbonate ore essentially in horizontal beds. Early operation of this underground deposit attempted to apply a long wall method. Future

operation will use some variation of room and pillar mining.

The Naopa deposit, some 20 km south and west of Otongo is a major orebody of manganese carbonate but the ore beds are severely folded and fractured by faulting. The orebody has been drilled on 50 meter centers with over 67,000 meters of holes. There is a "high grade" side to the orebody on the west, and a lower grade side on the east. Total depth of the proposed open pit would be 200 meters.

Plans to strip and mine the Naopa orebody are well advanced. Premine stripping would call for 2 years at 2 million cubic meters per year. The overall pit ratio is 9 to 1 (meters to meters). A 28-year life at 300,000 TPY has been projected.

Although the strip ratio is high, waste disposal is easy and involves no uphill hauls. Drilling and blasting will be required and loading will be with Payloaders and 50-ton trucks. A second nodulizing kiln would be installed near the mine. Approximate cost to bring the mine into operation is 3 billion pesos (approximately U.S. $20 million.)

Due to the high probability that the run-of-mine ore will contain wall rock and low grade beds of carbonate, a heavy media plant will probably be required at this deposit.

Tetzintla Heavy Media Plant

Beneficiation of ores from the Tetzintla Unit is limited to treatment by heavy media and by calcination. The calcination or nodulizing kiln is discussed later.

All underground ore from the Tetzintla No. 2 mine is treated by heavy media to separate high manganese carbonate beds from lower manganese beds. Rejection of liberated waste rock is not required because none exists.

The heavy media plant is strictly a "bob tailed" unit by conventional standards. Run-of-mine ore is crushed only through a jaw crusher to essentially minus 4". (Due to parting along bedding planes, much of the jaw crusher product is slabby and often 6" in long dimension). The crusher product is conveyed to a single combination washing, sizing and dewatering screen equipped with a 3/8" bottom deck. The - 3/8" by 0 flows into a dewatering bin through a gravity chute. The + 3/8" material is passed directly to a Wemco drum and separated at a density of 2.9 to 3.10, using spherical ferrosilicon. Two-stage 30" diameter electromagnetic separators recover the media. Medium loss is reported to be 140 grams per ton, or 0.31 lbs. per ton.

Feed rate averages 60 TPH and concentrate weight recovery is about 60%. The - 3/8" washings are trucked to stockpile and the float product is also stockpiled.

It is only logical to expect that a marketable concentrate could be recovered by either jigging or cycloning (with medium) the minus 3/8" washings. Likewise, crushing the + 3/8" float product to say, minus 1", followed by either a second stage of heavy media or jigging, should yield additional recovery. Such additions to processing could be installed in the future.

To illustrate the low cost of labor, an underground miner's direct wage is 550 pesos per day ($3.70). Production bonuses are also paid but only to miners; the kiln operation does not participate at this time of reduced output.

Tetzintla or Otongo Nodulizing Kiln

The nodulizing kiln is a Traylor unit, 375 feet long with a 16.5 foot diameter (except for the 20.5 foot diameter "bell section" near the discharge end). It is fired with two main burners fueled by low sulfur natural gas delivered by a 6" diameter high pressure pipeline from Mexico City. There are two - 500 HP kiln drive units. The main exhaust gas fan is 600 HP. There are two 300 HP fans on the grate-type cooler. The primary combustion air fans include

one 350 HP and 2 - 150 HP. The kiln facility design was understood to have been by Bethlehem Steel Engineering Co.

The kiln feed rate is 2600 TPD of carbonate ore crushed to - 2" by 0. Weight recovery of nodules is 60 to 61%.

The normal problems of kiln "ringing" have been experienced and overcome. Use of the boring bar and 10-gauge shotgun slugs control normal ringing problems.

The main stack gas exits to atmosphere at 300°C. (450°C on the grate cooler.

The quality of the nodules is excellent and the only major problem evident at the operation is the high dust content of the stack gases. The existing de-dusting equipment is obviously inadequate and causes severe pollution problems as well as losses of manganese units. Corrections are currently being studied.

Typical nodule assays and structure, as taken from a 1982 shipment from Tampico, were as follows:

	%		%
Mn.	39.10	CaO	10.00
Fe	8.0	MgO	9.33
SiO_2	14.3	S	0.37
Al_2O_3	3.25		

Physical structure :

	%		%		%
+2"	5.1	+½"	26.9	+3/16"	0.7
+1"	26.3	+3/8"	12.0	+1/8"	0.3
+3/4"	20.6	+¼"	6.6		

Density = 1.75 MT/cubic meter.

Fuel consumption was reported to average 107 cubic meters of natural gas per MT of nodules. (Calculates to be 3,776,000 BTU/MT). The only heat recuperation is from the cooler to preheat primary air to the burners (250° to 300° C.). Cost of the natural gas was not obtained.

Usual buyer specifications for nodules place a limit of 15% minus ¼" on the fine fractions. Autlan estimates from 8 to 12 "drops" are involved in handling the nodules between the kiln and Japanese buyer.

High alumina refractories are used in the ringing zone. Original refractory bricks have all been replace with castables.

It is understood that the direct operating cost per ton of nodules (mining and nodulizing) is around 1100pesos or $7.35 U.S.

Otongo Townsite

Near the nodulizing kiln is the townsite. All construction is with concrete blocks and all modern facilities are provided including medical center, market, chapel and schools. A 4-story 50 room hotel is provided for single employees and guests. Potable water and sewage facilities are also provided.

All facilities receive electric power from the transmission grid, backed up with power generated in the Company's natural gas fueled Worthington diesel plant which incorporates 4 - 2500 KW units. Cost of power from these units is stated to be very attractive.

Warehouse and Maintenance Shop

District offices and warehouse for supplies and parts are located near the nodulizing kiln. A heavy duty maintenance shop equipped with presses, boring machines, lathes, electrical rewinding, welding and cutting machines, tire repairs, etc. is adjacent the warehouse. Bridge crane service simplifies major maintenance work.

Personnel

The labor force at Otongo totals 200 of which 25 are school teachers and 31 medical staff. There are 54 in the maintenance shop. (Some special maintenance work is contracted to outside shops such as Caterpillar). Miners number 80 in both open pit and underground.

III. Tampico Port Facilities

Minera Autlan's stockpiling and shiploading facility at Tampico consists of a truck dumping hopper for the 30-ton tractor-trailer units owned by the company and for the 10 to 15 ton end-dump trucks of contractors. Nodules are transported over a 48" belt equipped with a Merrick Weightometer to a combination slewing stacker-reclaimer mounted on rails which position the loader in the center of the dock. Product can be stockpiled on either side of the rails. Stockpile capacity is 75,000 MT total of which 60,000 MT can be placed with the stacker only (no bulldozing or front end loaders).

There are no reclaim tunnels; stockpiled material is reclaimed by front end loaders (5CYD) and dumped into the truck hopper. Loading rate is 1500 TPH initially and then decreases as the haul distance from stockpile to pocket increases.

The dock is a floating pontoon type, fixed in position with two hinged yokes. Dock length is 500 feet. Fendering is by solid timbers fixed to the dock. There is 33 feet of water alongside and 38 to 40 feet in the main channel of the inland lagoon. Tide variation is only about 2 feet.

The largest cargo ever loaded was 28,500 MT on the MS Red Sky, bound for Japan.

Autlan also stockpiles and loads out dry cement clinker and has a capacity of 25,000 tons on the west side of the nodule stockpile area. The clinker is delivered by road trucks.

There appeared to be little problem from dusts because of the minimum fines in the nodules. Neighboring facilities include a magnesia plant and a Pemex oil refinery.

Minera Autlan owns 36 of the 30-ton road trucks and presently has scheduled these for one round trip per truck per day from Otongo to Tampico. Transport cost over the 260 km haul (75 Km of sharp curves and descending grades, Otongo to Huejutla)

were reported as 1400 pesos per ton, or $9.33 U.S. This would be 5.8 cents per metric ton mile and probably reflects the relatively low labor costs and good surface on the all black-top highway.

IV. Tamos Unit - Electric Smelting

The Tamos unit of Minera Autlan is located some 20 km west of Tampico alongside a 230,000 volt electrical transmission line of the Mexican power system. It is primarily a ferromanganese production unit which converts Otongo nodules to ferromanganese.

The Tamos industrial site is about 1 mile long and ½ mile wide. It is served by a railroad spur and by black top highway. Tamos is the largest electric smelting unit of Autlan. An older smaller unit is located at Teziutlan (about 250 km east of Mexico City and over 500 km from Molango by highway). Originally, this unit was a copper smelter and had its own hydro power unit using Pelton wheels. It has since been converted to ferroalloys. Autlan also owns electric furnaces at Mobile, Alabama which produce ferromanganese and silicomanganese (capacity 41 megawatts).

At Tamos there are two electric furnace plants, one of Japanese design and one of German design (DeMag). The Japanese plant was completed in 1974 at a cost of 1 billion pesos. In 1976-1977 the German plant was completed at a cost of 1.4 billion pesos.

The two Japanese furnaces each has a capacity of 15,000 MVA. The two German furnaces are smaller and are designed to slowly rotate, making possible the manufacture of ferrosilicons.

A small induction furnace has been added to the Japanese plant in order to utilize the crushed fine ferromanganese fractions which are screened from the lump products.

The 1983 projected production calls for:

	MT
Ferromanganese High Carbon	101,000
Ferromanganese Medium Carbon	22,000
Silicomanganese	17,500
Ferrosilicon	10,500
Total	151,000

The grade of the FeMn for national use is about 72-74% Mn. For export the grade is 78-80% Mn.

Feed materials to the Tamos plant include, annually:

190,000 MT of nodules
80,000 " of imported high grade Mn (from Africa and Australia)
35,000 " coke (-3/8" x ¼")
27,000 " quartz

The fine coke is briquetted in a 50,000 TPY Komarek-Greaves machine using sequentially molasses and quick lime. The briquettes are pillow shaped.

Another raw material is oxygen, used to make "medium carbon" ferromanganese.

A large raw material stockpile is located adjacent both plants. Plant No. 1 (Japanese) can stock 20,000 tons of Autlan nodules, 12,000 tons of imported ore and 5,000 tons of coke fines. Stockpiles for Plant No. 2 are smaller and include wood which is converted to chips for furnace feed.

Plant No. 1 has a very sophisticated raw material feeding system, completely instrumented with weigh scales and automatic feed mix control. Raw materials are blended and distributed to 8 feed pipes around the periphery of the furnace. Because the furnaces are of closed top design, the top of the furnace is under slight pressure and CO is vented and burned at the top of the plant (some dust is also vented).

The furnaces use paste electrodes over 1 meter in diameter. Electrode consumption was reported to be 14 kg. per MT of alloy.

Each furnace crucible was 9.0 meters in diameter with 4 meters depth of slag plus metal. There are 2 tap holes each for slag and metal. High alumina refractories are used with mostly carbon bricks in the crucible.

Current to the electrodes was at 160 volt and 88,000 amperes. Adjacent transformers provided varying current characteristics.

Most of the electric power is generated by thermal power in a coal-fired plant in the Federal power grid. The cost of power was said to be from 1.2 to 2.2 pesos per KWH (0.80 to 1.47 cents U.S. per kwh).

The German plant utilized "open top" furnaces which are fed from the hearth level by "spoons" or cannisters. Blended feed material is dropped by gravity into bins located around the periphery of the furnace. Constant smoothing and filling of the charge around the electrodes is required by an operator and trolley-electric charge car. All furnace gases are burned at the top of the furnace. High velocity hot gas flues convey furnace gases to a dust collecting plant which uses bags for collection. Vented gases were relatively clean.

Furnace charge materials were stockpiled and blended by alternate bedding on a large concrete pad. The blended charge then was loaded with FE loaders and fed to the plant bins. This system obviously was less efficient than that employed in the Japanese plant but also less expensive capitalwise.

Ferromanganese slags find uses as concrete aggregate. Because of the inherent self fluxing characteristics of the Autlan nodules, slag volumes are low, and ferroalloy qualities are high. The major advantage claimed for Autlan FeMn products is the low silicon content (0.2% Si) whereas U.S. specs call for 1.5% Si maximum. In addition, there is a very low phosphorus and arsenic content and no objectional alkalis.

Minera Autlan's products include:

MnO_2 (battery grade), 48% MnO_2
Ferromanganese (high carbon), 72 to 80% Mn
Ferromanganese (medium carbon), 80-85%Mn
Silicomanganese, 60-68% Mn, 16-18% Si
Ferrosilicon, 50-52% Fe, 45-50% Si
Ferrosilicon, Fe Si, 74-76%
Ferrochrome, Fe, Cr, 58-65%
Ferrosilico magnesio, Mg 5-10%, Si 44-48%
Manganese nodules, 39-40% Mn, 13.8% Si

Total employment at Tamos is 590 divided into 132 empleados and 458 obreros who are unionized. Productivity is reported to be 20 tons per person per month. Power consumption is 57 megawatt hours per person per month.

Summary

It is safe to say that Minera Autlan's reserves of 27.2 million metric tons represent the largest proven reserves of manganese ore in North America. These reserves are well defined, accessible to operation, and amenable to proven processes of mining, up grading and conversion to ferromanganese products. The company is long established, capably staffed and managed, and important to the Mexican economy. In addition, the Mexican government, through Nacional Financiera, has a 28% equity in Minera Autlan.

There is little doubt that additional exploration will markedly increase present ore reserves.

It is readily apparent that the Autlan manganese ores and products could become a significant reliable source of manganese to the U.S. Shipment by truck and rail is possible, thus eliminating risks of sea freight.

Admittedly, the grade of Autlan nodules is below 48% Mn (World markets are based on 48% Mn minimum) but there are no impurities and the product is accepted in the steel industries

of several countries. The self-fluxing characteristics of Autlan nodules are distinctly advantageous.

A sober appraisal of the future viability of Minera Autlan must recognize that continued availability and supply of both the low sulfur natural gas and cheap electrical power are essential. Both of these essentials are under full control of entities of the Mexican Government.

Under long established Mexican mining laws, foreign ownership of a Mexican mining company is limited to 49%. This is the maximum equity a U.S. company could obtain in Minera Autlan. However, by investing in Minera Autlan, a U.S. corporation could acquire a holding in a leading mining and electric smelting company, one that has large manganese ore reserves and is actively exploring for other minerals. Present production capacity can readily be increased.

Inasmuch as some manganese carbonate ores have been successfully concentrated by flotation, it is recommended that this avenue to utilization of the lower grade (25% Mn) Autlan carbonate ores and gravity rejects be thoroughly investigated. Obviously, this would call for fine grinding to achieve mineral release, and large volumes of process water. Moreover, any manganese-rich concentrate would require agglomeration. The product from such a conentration step, however, should make a premium grade agglomerate, and greatly enhance future operations of Minera Autlan.

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