COMMODITY REPORT

Small scale gold mining in Nicaragua

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Photos by Bengt Fagerberg

In 1982 the gross value of global small-scale gold mining was 1.6 billion US dollars. This article examines the importance and prospects of small-scale gold mining in non-industrialized countries, with special reference to Nicaragua.

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Introduction

There are many developing countries in the Third World which have failed to take advantage of their natural resources of small gold deposits to underpin frequently overvalued currencies. Even some countries which in colonial times had significant gold mining sectors, have neglected the oportunity afforded by gold to develop their economies. Gold has experienced a dramatic price increase and have more than doubled in real value since the early 1970s. At present illegal gold mining is thriving in many third world countries and the gold is sold to the black markets. Attempts to stem such activities — which are a serious drain of a valuable natural resource — have seldom proved effective. But Nicaragua is an exception where a primitive and illegal activity has been converted into an efficient and legitime trade supported by the state. The example of Nicaragua can illustrate a possible way out of inefficiency and underdevelopment within the gold mining sector, although the present economic situation in Nicaragua, as in most non-industrial countries, does not allow a fast and easy reconstruction of their small-scale mining activities.

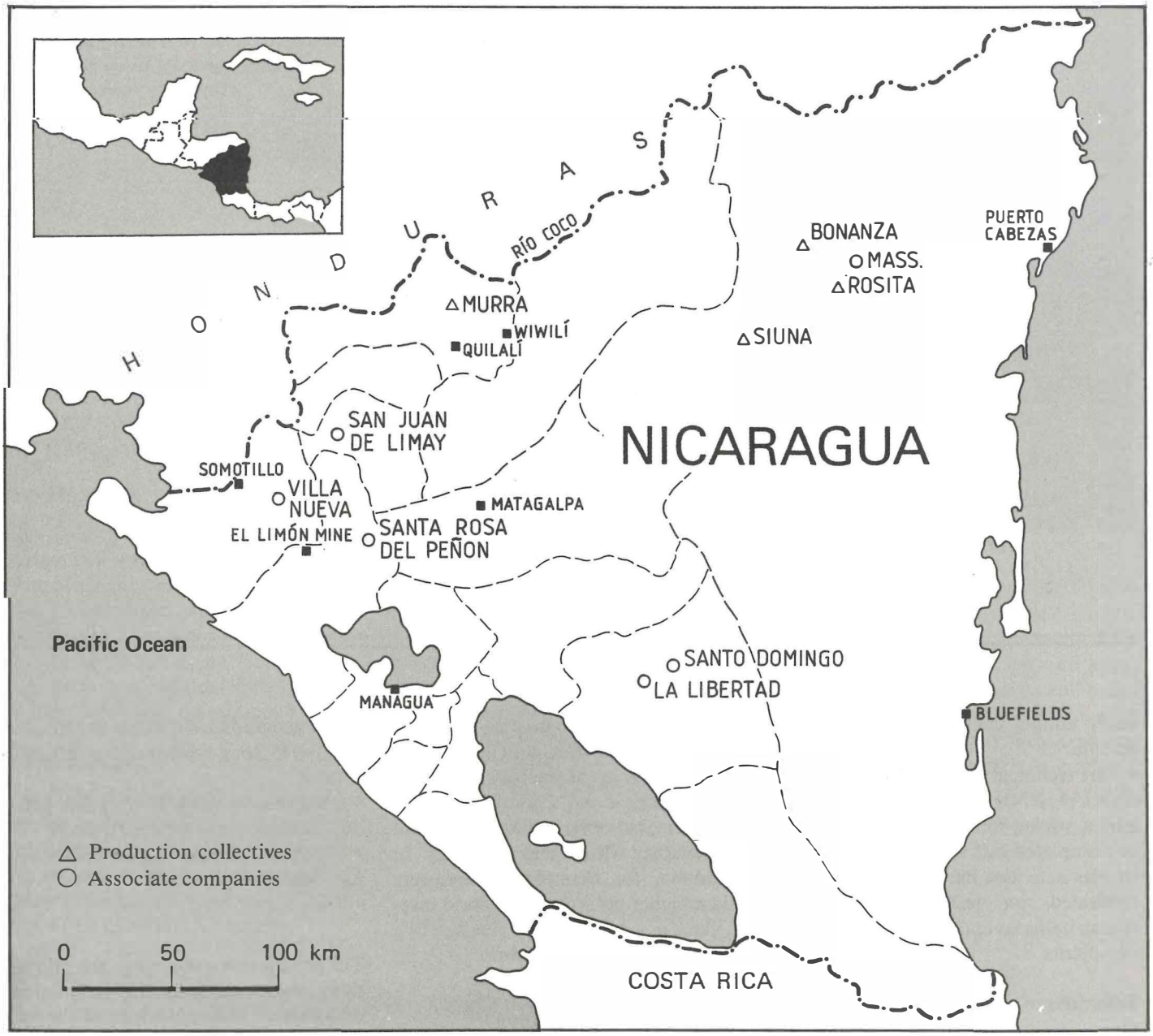
Gold mining in Nicaragua — an historical background

The history of the individually working miners, or "güiseros" (a local name for the country-side people dedicated to gold mining), can be said to have started in 1889, when the first placers of gold were found by people sampling gum-trees at the riverside of Siuna Was. From this date the small mining activities in Nicaragua have been maintained by local people, working on their own or in small groups. The main activities was first concentrated around the mining district of Siuna, 140 kilometers from the Atlantic coast. Mining near the Pacific coast (El Limón mine) started at the end of the 19th century. Gold mining successively spread to other zones in northeastern Nicaragua. The rumours of gold also attracted international mining companies to the area where they later got established and opened mines and built modern concentration plants (at Rosita 1906, Siuna 1909, and Bonanza 1920). Augosto Sandino organized small mining cooperatives in the 1920s in Quilali, Wiwili and parts of river Coco. Mining in the central parts of the country (La Libertad-Santo Domingo) started about the same time. Small plants using stamp batteries and amalgamation were installed in Chontales (Santo Domingo) in 1910.

At several of the small mining centres mining was done by means of panning, sluices, stamp batteries, "arrastras" (grinding by dragging stones) and "molinetes" (manual mortar grinding). The gold was recovered by amalgamation, that is with mercury which subsequently is heated to liberate the gold. During the 1970s small-scale mining was mainly concentrated to the mining districts in the northeast (Siuna, Bonanza and Rosita) and to the central parts of Chontales (La Libertad-Santo Domingo). In Santo Domingo a stamp battery to which the miners payed a third of their gold for the right to use the installation existed up till the nationalization. At the Atlantic coast local buyers speculated in the gold price and the mercury trade. It can be said that before the revolution, at the 19 of July 1979, small scale mining was on the decline, no one bothered about the activity and mining took place without any development of new methods. The "güiseros" were thus strongly limited by their working methods, which have remained the same for a century, and had no hope of better living conditions or technological advances.

The present situation for the güiseros in Nicaragua

The nationalization of the mines in 1979 was a necessary step, as the former mine owners declined to continue their mine activities, which had come to a stand-



still during the struggle against the regime of Anastasio Somoza Debayle. Seen against this background the decisions taken by the new government can be seen as an encouragement to technical renovation, to a rational exploitation of small gold deposits and to a commercialization of the gold extracted.

What has the nationalization meant to the güiseros? First of all a liberation from human exploitation, from concession owners and from those who ran the processing plants. When the nationalization took place the natural reoursces were bought from the transnational companies and expropriated from individuals directly associated with the former regime. In this way zones that earlier had been closed were opened up for the güiseros, who started to pan localities close to the old dressing plants and from the waste. Small miners who earlier had left their profession and gone back to agriculture now returned to mine places like Somitillo and Santa Rosa.

As a consequence of the nationalization of the Nicaraguan mines on November 2nd 1979 a small-scale mining directory, PEMIN (Pequena Mineria), within the Ministry of Mines was formed. The initial objectives of the directory were:

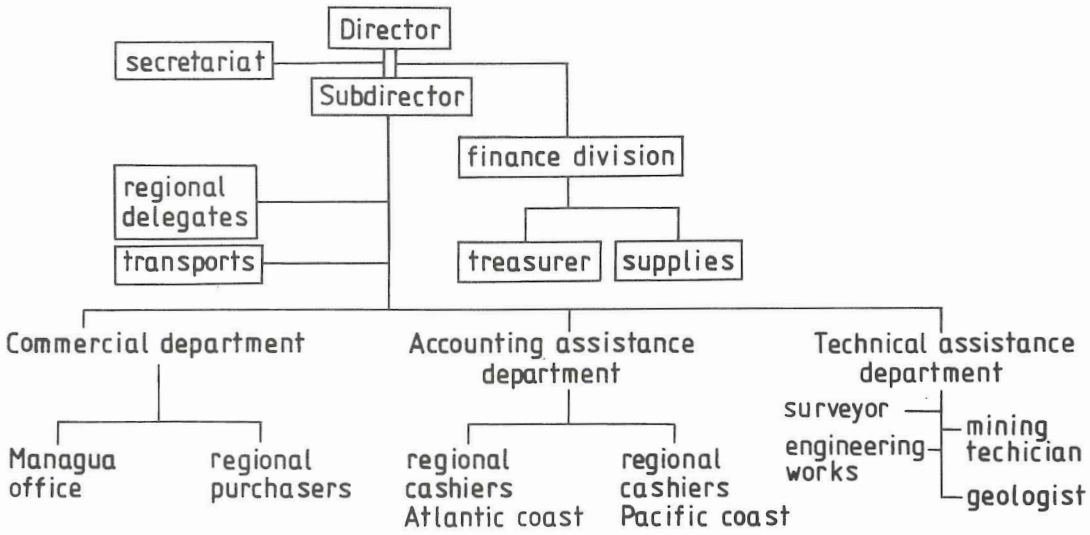
- to create conditions that permitted a direct channel, for the commercialization of gold, from the güiseros to the Ministry of Mines (INMINE).
- to raise the living conditions of the güiseros, through the establishment of a solid organization in accordance with the necessities of the miners and within the general lines of the revolutionary process.

The present organization of PEMIN

Since January 1985, PEMIN is a division within the Ministry of Mines, which before was an independent authority, but which now falls under the Ministry of Industry. PEMIN has the following functions, which are divided into three departments under a Director and vice-director (Fig 1):

- The commercial department, whose principal function is to buy and sell the gold produced by the "güiseros".
- The accounting assistance department, which registers the operations at

Fig. 1 Organization scheme for PEMIN



each mining centre and presents the results.

• The technical assistance department, which presently consists of one engineer and a mining technician. The staff will be completed with a whole-time geologist. Its activities has mainly been concentrated on restoring abandoned stamp batteries and on improving working plants.

Commerce

The gold extracted by the "güiseros" is bought by PEMIN at trade centres in the major production areas. PEMIN then sells the gold to jewellers, dentists and the Central Bank (Banco Central de Nicaragua). Gold bought by the Central Bank is stored or used for transactions of national interest.

The decline in production after 1981 was caused by constant prices during a period of inflation, which led to an increased black market. The situation changed rapidly when the government decided to raise the price for crude gold at the beginning of 1984. This decision led to a rush of people who found it worth while to extract gold and sell it to PEMIN instead of to the local black market buyers. It is a well known experience that when a government is not prepared to pay the equivalent to the world market the black market starts to flourish. With the present situation for many Third World countries, with heavy debts and little reserves of foreign currency, it must be wiser to pay a good price in local currency in order to obtain the gold for exchange with foreign currency. In Colombia, for example, miners were paid a higher price than the world market price during 1984. This resulted in a drastically higher production.

Different types of mining organizations

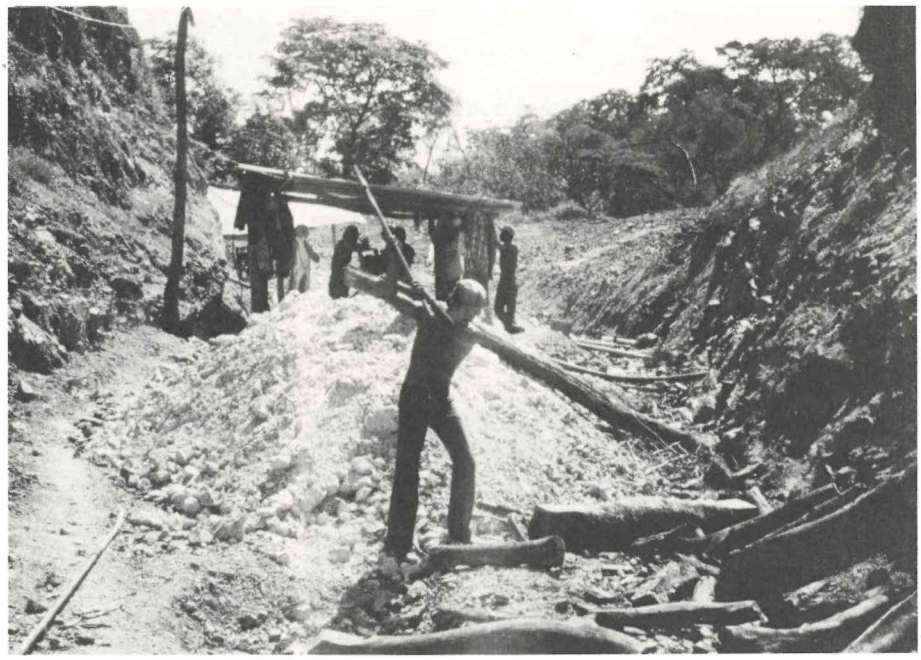
The güiseros can be grouped into two types of organizations: associate companies and production collectives. The two groups are distinguished by the methods and equipment used.

The members of *associate companies* have their supply of material and working tools guaranteed by the state, and have agreed to sell their production to the state, through the PEMIN organization. Their members work individually, or in small groups of 2 to 3 persons. These are normally characterized by:

• they work on individual conditions
• the distribution of earnings from extracted gold is on the basis of what each member has produced
• the working tools are individually owned
• the working areas are widely distributed geographically, many groups are isolated for long times and thus difficult to assist
• many miners work at irregular periods, intermittently with agriculture
• to extract the gold they normally use pans and sluices

The *production collectives* are collectively organized, from the assignation of different fields of activity in the mines to the moulding of the gold. Income from the gold produced is divided according to each man-day worked. Some characteristics of the collectively organized miners are:

• they can have up to 60 integrated members
• the working tools are collectively owned
• they work within defined areas within regulated working hours
• their sphere of activity is within a close space
• they normally use stamp batteries, manual mortars or "arrastras" to crush and grind the gold-bearing rock
• their working conditions permit a better technical assistance, a better economy and increased inversion facilities compared with the associate companies



Mining of a quartz vein. The shaft is situated under the wooden structure in the background. Germán Pomarez Collective near Somotillo.

PEMIN mining centres

Details on employment and production in the Nicaraguan gold industry in 1983 are given in Table 1.

The centres of gold extraction are situated in the following regions (for location see map on p 31):

Western region

The collective production centre of "Germán Pomares Ordónez", at 178 km from Managua between the municipalities of Somotillo and Villanueva, department of Chinandega. The collective of "El Quebrachal", at 135 km from Managua, near the municipility of Santa Rosa del Pénon, department of Léon.

Eastern region

The collective of small miners at Santo Domingo, located 200 km from Managua department of Chontales. The mining collective "Pedro Altamirano", located 175 km from Managua in the village of La Libertad, Chontales.

Northern region

The mining collective of "Heroes and Martires de San Juan de Limay", at 245 km from Managua, department of Esteli. The associate company of Murra, 280 km from Managua, department of Nueva Segovia.

Northeastern region

The associate companies of Siuna, Rosita and Bonanza, located 375—480 km from Managua, department of Zelaya. These mining centres can now be reached through a newly constructed road from Matagalpa to Puerto Cabezas.

Exploration methods

In both the collectives and the associate companies the mines are exploited manually. The equipment is limited to shovels, hoes, crowbars, hammers and chisels. To extract gold, miners sink shafts down to 20 meters into the quartz veins and dress the shafts provisionally with fragile wood. Only in few cases underground workings of more adequate constructions are made. The members of the collectives usually open up underground mines while the miners of the associate companies prefer open pits or pan the sediments or wastes. No type of ventilation equipment is used and the illumination consists of carbide lamps. The small-mine plants have a capacity of 0.3—15 t/day and are fed with auriferous quartz ore from shafts and adits in different, often parallel veins. All drilling is done manually and no dynamite is used. The ore grade is determined by panning tests (often using a black-

Table 1

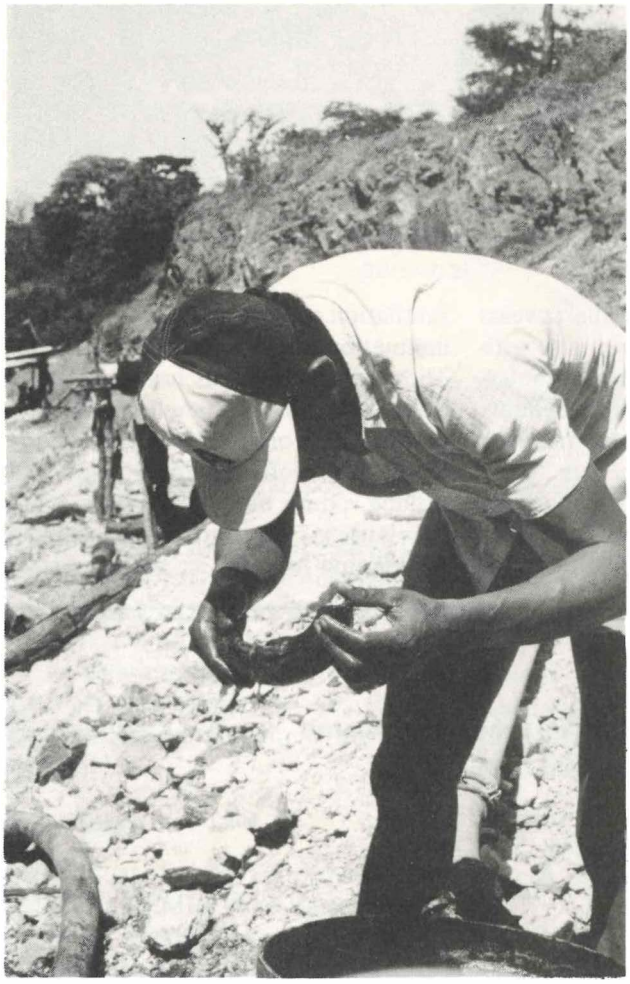
Gold obtained from PEMIN's production centres
(in troy ounces)

	1980	1981	1982	1983/Sept
Production collectives	804	1 320	918	541
Associate companies	1 180	1 906	1 614	536
Managua and others	105	142	16	127

Place/type	Number of employees	Gold ounces/year
Small-mines		
Somotillo	60	900
Santa Rosa	25	120
Limay	20	210
Santo Domingo	80	930
La Libertad	4	60
Placers		
Murra	0—100	90
Bonanza	80	300
Rosita	150	1 020
Siuna	300	2 520
Minnesota	varying	300
Total	**780**	**6 300**

A güisero (miner) determines the gold content of the rock by means of a cow horn (below left).

The gold bearing rock is crushed by hand (below right).



ened cow horn). If the gold content is less than 3 g/t the material is discarded. The grade of the mine product is often 5—10 g/t but can sometimes be considerably higher. The mined ores are brought to the processing plant by mule. The subsequent treatment varies from place to place but is generally mechanized to some extent. For example, stamp batteries are used for crushing/grinding of the —50 mm crude ore to about —1 mm. The gold is recovered by amalgamation at La Libertad in combination with gravity separation. At Somotillo all crushing/grinding is done manually but a stamp mill will soon be erected.

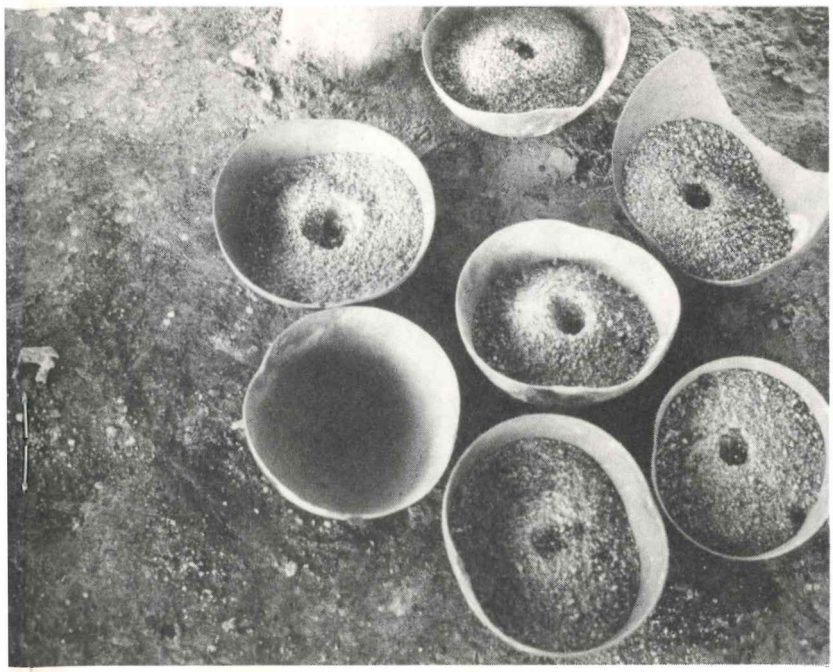
Processing methods

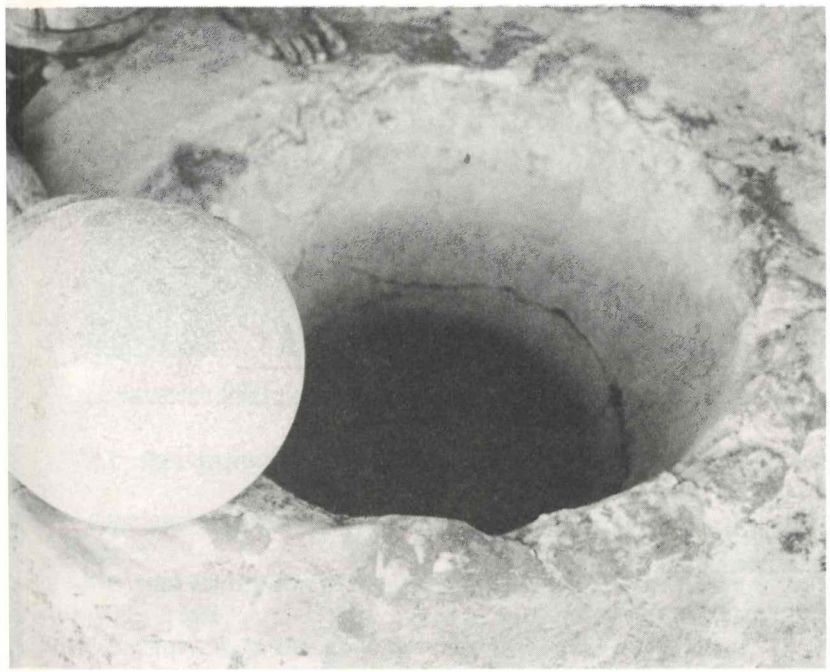
Stamp batteries (Bocarte)

The mineralized rocks brought to the plants have a size of 2 inches and are ready for grinding. They are fed into the batteries by hand and pulverized by the pestles, while water is added together with some drops of cyanide. The ground product is discharged through a metal net of 10 mesh and is then poured over an inclined copper plate covered with mercury for amalgamation of the free gold. Every eight hours the plate is cleaned with a spatula to recover the amalgam which later is squeezed to get rid of as much mercury as possible. The metal left has still remains of mercury which is eliminated by evaporation when the material is heated in a bottle. The mercury vapor is condensed for reuse in the process.

Arrastra

This is an antique method introduced by the Spaniards when they first arrived to Central America. The arrangement consists of a wooden cross centered around a pivot. From the arms of the cross four grinding rocks are hanging, weighing approximately 50 to 100 kg. The rocks are dragged over a flat surface thus grinding the ore while water is ad-

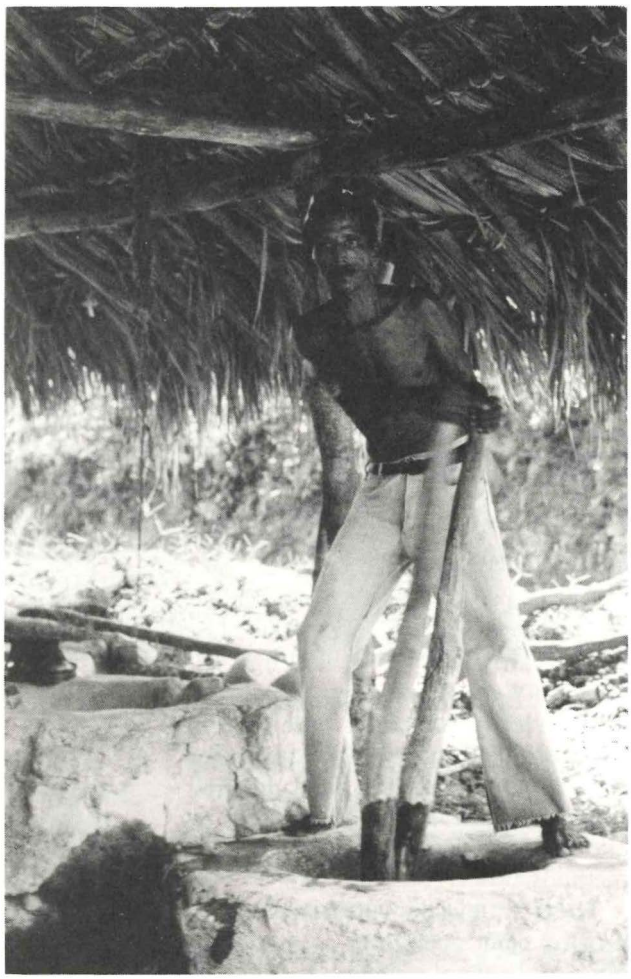




The crushed rock is laid in a calebash together with mercury (left).

The crushed rock is grinded in a mortar with a rounded stone as pestle (below left).

A güisero grinding the crushed rock in a "molinete" (below right).



ded. The free gold is concentrated gravimetrically. After a fortnight the sand accumulated in the basin is removed and panned in a sluicer with riffles and jute cloth. The waste is finally passed to an amalgamation copper plate, from which the gold is recovered as described above. The capacity of the arrastra is 2—3 tons/day.

Molinete

The molinete is a simple grinding mill consisting of a mortar excavated in the rock or moulded in cement. The grinding is done after addition of mercury for about 10—20 minutes by help of a round stone attached to a V-shaped wooden handle. The crushed material (2.5 kg) is gathered in calabash bowls to which mercury is added. The amalgamated gold is then recovered from the ground ore by washing and heating for removal of mercury.

Sluice

A sluice recover free gold by gravity. The sluices used by the miners in Nicaragua are made out of wood, normally 0,4 m wide and 1,5 m long covered with jute. Above the yute cloth riffles are arranged to serve as gold particle traps. The sluice is placed in an inclined position and the sand and water are allowed to flood through the sluice. The free gold is recovered gravimetrically and attached to the jute cloth, which is removed after 6 to 7 hours and washed to recover the gold-bearing sand. This product is later panned together with mercury. The sluice is normally run by two persons.

The pan

The pan is the most simple method used by gold placer miners and explorers all over the world. The pan can be made out of wood, metal or plastic. In Nicaragua a cow horn is frequently used. Sand and stones are gathered in the pan which is moved continuously under water and slightly inclined to allow the heavier minerals to concentrate in the middle of

the pan while the lighter material floods over the edge. When the gold particles are very fine, mercury is added to the concentrated material to extract the gold. The panning can be done in several steps and is also used to estimate the gold content of crushed rock material.

Except the above-mentioned methods, a few others have been used in Nicaragua. In the Cerro Dorado Mine (province of Zelaya Norte) ball mills, jigs and Wifley tables were used. Earlier they also used recuperation with cyanide on the waste from the stamp battery. These methods have been forgotten as the persons who used the machinery left the country.

Mineral dressing investigations

Mineral dressing investigations of ores and products from Pemin's small-mines in Nicaragua have been performed at the Department of Mineral Dressing, University of Technology, Luleå. The aim of the investigations have been to establish the recovery of gold with the present plant practices and to find means of increasing gold recovery by alternative, less health-hazardous methods.

The first stage in the research for improving plant operations covered sampling of the plant products, to establish present metal recoveries. The second stage involved collection of representative ore samples, followed by laboratory studies of alternative ways of increasing the metal recovery and thus the overall economy of the operations. The laboratory studies comprised mineralogical examinations, amalgamation tests, cyanidation investigations and gravimetric separation tests. All the feed and concentration products were analysed for gold by fire assaying.

The gold recovery at the amalgamation plants was below 50 per cent, sometimes considerably lower (Fig 2). This result is not surprising as a literature review on methods used last century with stamp battery/amalgamation mills

Fig. 2 Gold content in tailings after amalgamation as function of particle size (logarithmic scale)

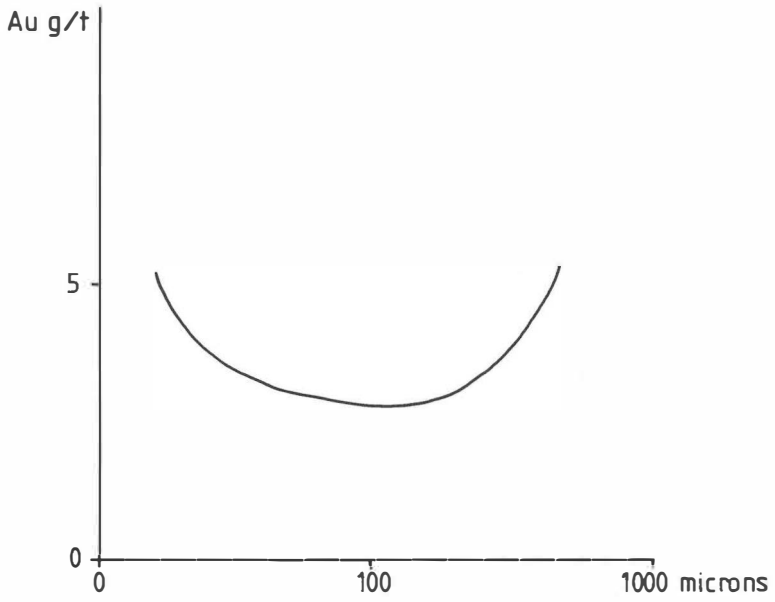
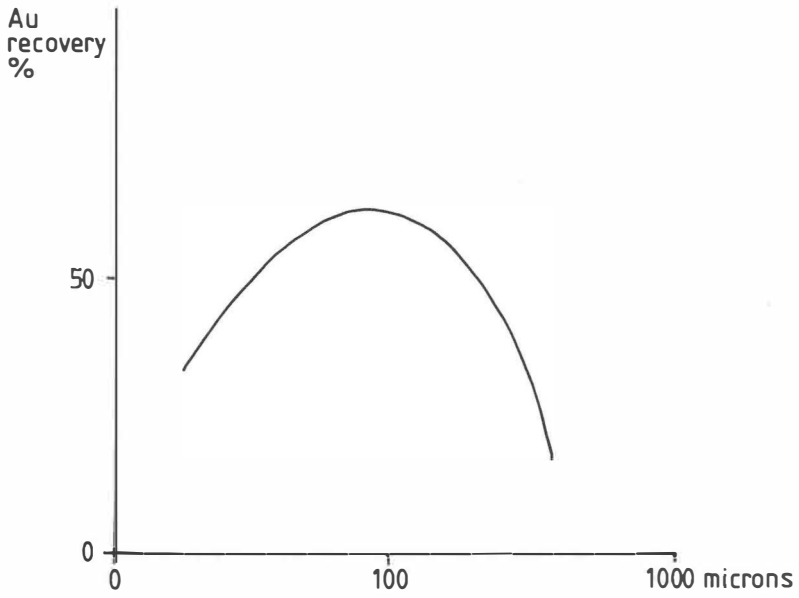
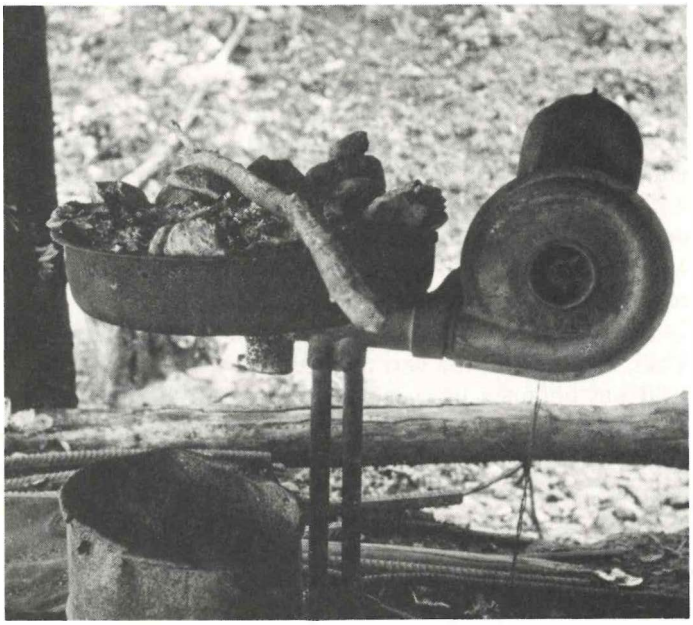


Fig. 3 Gold recovery as function of particle size at amalgamation



After grinding the material is liberated from the amalgame (left). The amalgamated gold is pressed in a linen and then heated in a fragua, where the gold is liberated from the mercury, which is recovered in condensed form in the bucket (below).



Amalgamation

Amalgamation consists of three processes:

- partial absorption of mercury on the gold surface
- mercury wets the gold but not the gangue
- gold sinks in mercury; gangue does not

A successful amalgamation demands that the gold must be liberated and amalgable, that the surface of the gold and mercury must be clean and that the receiving mercury must be proper. The application of amalgamation plates was common 1860—1925. The ore pulp, containing 10—20 weight per cent solids, was slowly passed over mercury-covered copper plates. When the mercury had become hard because of the gold, more mercury was sprinkled on to the surface until a proper layer of amalgam was obtained. This layer was then removed with rubber- or woodscrapes. The capacity of the plates was 0.5—1.5 tons of ore/m^2 and day. The requirement of mercury was about 30—50 g/ton of ore, and the gold recovery 50—88 per cent.

Cyanidation

The process of cyanidation was first introduced in 1887 and first in use at the gold mines in Witwatersrand, South Africa, in 1894. Today it is the most important gold recovery method used, sometimes combined with amalgamation of coarser gold particles. In nature gold occurs alloyed with silver and copper.

Large particles then produce galvanic cells which increase the dissolution rate. Very small gold particles are sometimes freee from alloys and the galvanic effect does not occur, i e the dissolution rate decreases. The reaction that take place during dissolution of gold in cyanide solutions under normal conditions have been fairly definitely established:

$$4\,Au + 8\,NaCN + O_2 + 2H_2O \longrightarrow 4\,NaAu(CN)_2 + 4\,NaOH$$

The requirements necessary for an easy dissolution are:

- the gold must be free and clean
- no impurities in the leaching solution that might inhibit the reaction
- adequate supply of oxygen in solution throughout the reaction period

The gold is precipitated from solution by passing the solution through steel vessels filled with zinc-dust or zinc shavings. The precipitate is then melted with borax, silica and other slag components to remove minor amounts of impurities. The end product consists of 50—60 kg gold bars, also containing associated silver. In most cases the bars are further refined by electrolysis.

(which were in operation all over the world at that time), showed that it was difficult to recover more than 50 per cent of the gold by this method, even if the technology was very sofisticated. The mineralogical examinations revealed that the gold particle size varied between 2 and 30 microns although individual gold grains may reach a size of 200 microns.

This result indicates good possibilities of recovering the gold by cyanidation and that amalgamation and gravity separations are less suitable methods due to the gold being finely disseminated. Thus, as expected, the best recovery of gold was obtained by cyanidation and the results improved with finer grinding (Fig 4—6). The effective recovery can thus be doubled, up to 80—90 per cent, even for treatment of the relatively coarse material from the stamp batteries. This is due to the existance of micro-fissures in the mineral grains which help the cyanide solution to reach the gold particles even if they are not completely liberated.

Some form of cyanidation is consequently recommended for the extraction of gold from the small-mine ores.

Different solutions to improve the production and gold recovery at the mining centres of PEMIN

During this study different solutions to improve the production and the recovery of gold have been discussed, and several alternatives have been presented. Some of these ideas will here be presented and commented on:

• Introduction of a mobile preassembled ore concentration plant, as for example the Sala Caravan Mill.

The advantage with a mobile mill is that the equipment can be moved from one place to another when a specific deposit is depleted. The price of such a preassembled ore concentration plant would be about 1 M USD. But as we cannot see the necessity to move around a small plant in Nicaragua the price does not jusitfy this solution under present condition.

• To feed the gold-bearing quartz directly into one of the existing mine plants.

This idea has many times been recommended as the most simple method to increase gold recovery from ore in the small mining operations. But the alternative has severe limitations. First the transport problem, to bring the ore from the PEMIN mining centres to the larger mines. Today there is a serious transport problem in Nicaragua and very little fuel is available. Moreover it is quite difficult to evaluate the gold content and thus the price of what is coming into the plants. Another problem is that the gold ore grade from the miners organized by PEMIN is much higher, sometimes several ounces, than the average gold content from the larger mines. This discrepancy could result in less recupera-

Table 2

Cyanidation with ore from Santo Domingo and Santa Rosa

Ore (Appendices 10—13)			Agitation time	Cyanidation tailings		Gold recovery
Type	Grinding K80 mm	Au g/t	Days	Fraction microns	Au g/t	Au %
Santo Domingo Duro	Coarse 2,4	15,8	3	Total	1,6	90
	Medium 0,46	15,8	3	Total	1,4	91
	Fine 0,12	15,8	3	Total	0,7	95
	Coarse 2,4	15,8	6	Total	1,5	90
	Medium 0,46	15,8	6	Total	1,4	91
	Fine 0,12	15,8	6	Total	1,6	90
Santo Domingo Suave	Coarse 2,2	4,3	3	Total	2,4	44
	Medium 0,22	4,3	3	+300	4,1	
				150	0,9	
				53	0,6	
				—53	0,3	
				Total	0,8	81
	Fine 0,09	4,3	3	Total	0,3	93
	Medium 0,22	4,3	6	Total	1,2	72
	Fine 0,09	4,3	6	Total	0,2	95
Santa Rosa	Coarse 2,5	14,1	3	Total	2,9	79
	Medium 0,7	14,1	3	Total	1,7	88
	Fine 0,12	14,1	3	Total	1,2	91
	Coarse 2,5	14,1	6	Total	2,6	82
	Medium 0,7	14,1	6	+300	4,1	
				150	0,8	
				53	0,2	
				—53	0,9	
				Total	0,9	93
	Fine 0,12	14,1	6	Total	0,2	98

tion from the gold originating from the "güiseros". Last but not least, a delivery of gold ore to the large mine would cause an organizational problem, in that the chain from extraction to production gold bar within the PEMIN would be broken and integrated with a more complex larger mining organization that now is struggling with serious problems to maintain its mines and production.

• Continued use of the present methods with stamp mills and amalgamation.

As stated earlier in this paper the recovery of gold with amalgamation methods is very inefficient and cannot be more than marginally improved. Moreover, the present method with amalgamation on copper plates is forbidden in most countries due to the health hazards involved.

• Heap leaching methods

An attempt to simulate heap leaching on ore from PEMINs plants was a failure. The fine material in the ore did not permit effective percolation. Heap leaching is probably not the best method on a rich gold ore such as that treated in Nicaragua; heap leaching is internationally used for large low-grade deposits.

• Installation of small 10 to 20 ton/day cyanidation plants

Small cyanidation plants in all major districts producing for PEMIN in Nicaragua would in our opinion be the best solution. Similar installations have been studied in Colombia (see below) and can be financed almost entirely with local currency and constructed within Nicaragua. The advantages are the small size of the processing plant, the good recuperation of both gold from veins and gold from old tailings, the low cost of inversion and the simple technology. The best result is obtained using agitation tanks for the cyanidation and zink percipitation. To avoid contamination of the surroundings the solutions can be recirculated within the dressing plant.

Treatment of gold material in Colombian processing plants

In Colombia the Ministry of Mines and Energy has recently designed a 30 t/36 h

Fig. 4

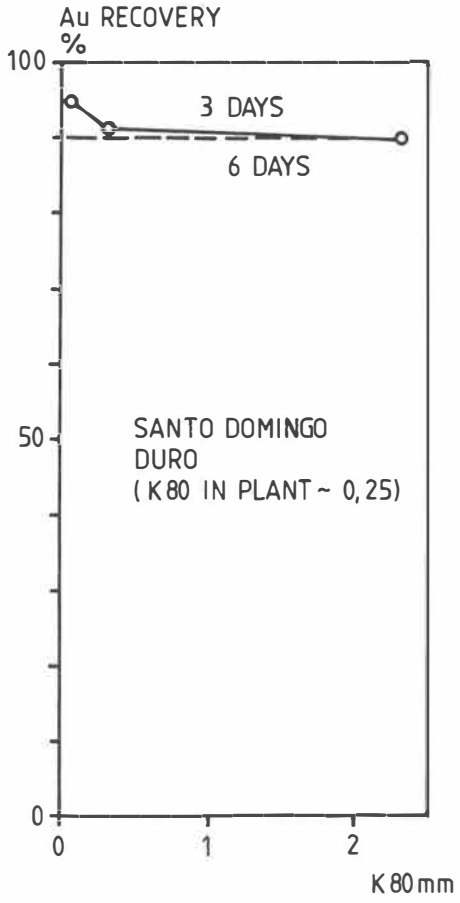


Fig. 5

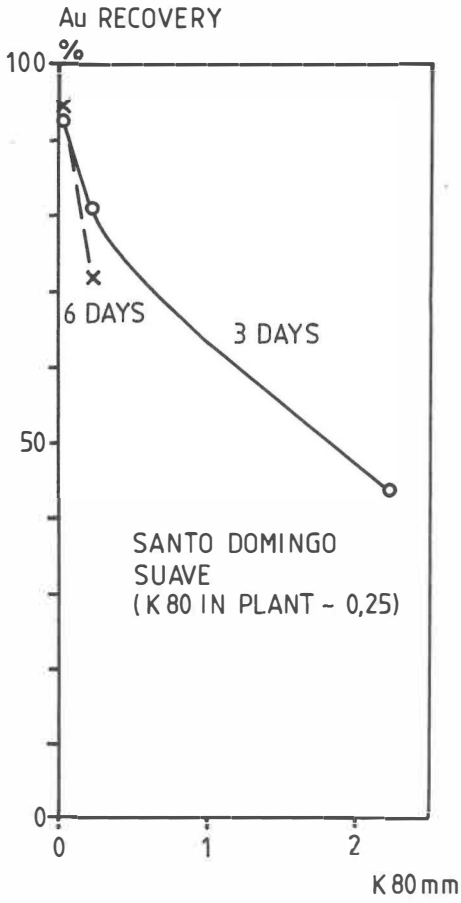
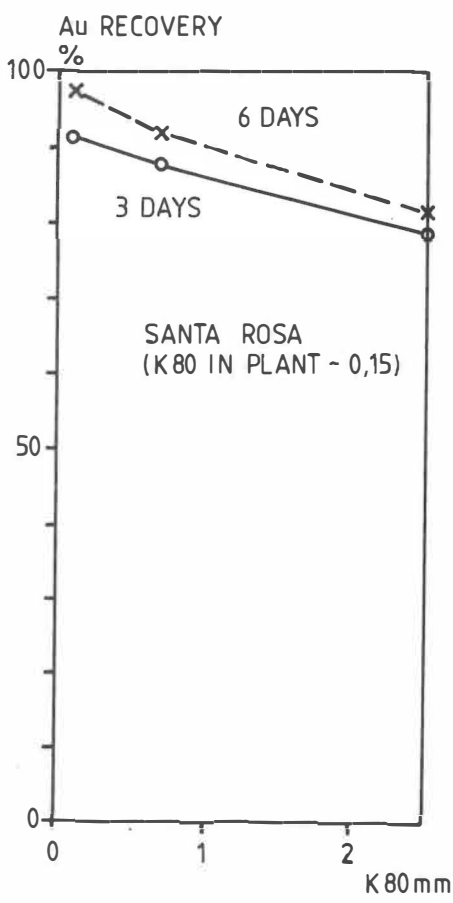


Fig. 6



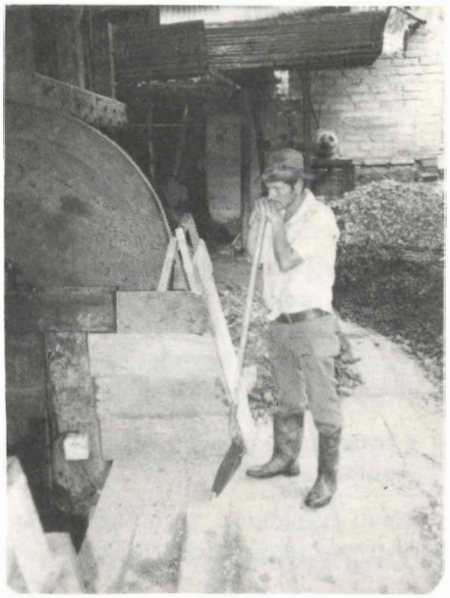
In Colombia the government is actively purchasing gold from the small-scale mining industry in order to limit black market sales of gold.
Photo from a stamp battery at the El Cerro mine.

plant in Cerro Cabezas, province of Medellin, which with small modifications could be used at the Nicaraguan small-mine centres. The major part of the equipment has been designed in Medellin and the welding of the tanks, etc, has taken place at the plant itself. Total consumption of energy is 55 hp. The technical specifications of the plant are:

Feeding capacity	26—30 t/36h
Gold in feeded material	18—26 g/t
Silver in feeded material	25—30 g/t
Particle size	74 per cent mesh —65 before treatment
	96 per cent mesh —65 after treatment

The gold-bearing tailings or crushed rocks are transported to the plant by mule or lorry and is stored in a cemented area with a capacity of 500 tons. As a first step the material is disintegrated in two vertical cells coupled in series and then washed in a hydroclassifier, type Larz, consisting of one container (2x8 m) with 4 valves for water discharge. The overflowing material passes a series of tanks for sedimentation of the fine material added with an aglutinating substance. the slime is let to settle and then transpassed to the agitation tanks by help of a Denver pump and gravitation. The washed material is then leached with cyanides in 6 parallel tanks, with agitation and conical bases (2x5 m, 4t/tank). An engine of 3 hp is mounted on each tank in order to facilitate the agitation. After 36 hours of agitation the engines are stopped and the solution is let out through holes in the sides of the tanks. Finally the bottom is opened to discharge the solids settled.

The consumption of NaCN is 3—4 lb/t gold-bearing sand and 10 lbs/t of CaO. In each tank five cubic feet of air is used each hour. The solution rich in gold (24 m^3/day) is pumped into a cement pile measuring 36 m^3 and with 6 individual compartments. Each compartment is coupled to two boxes with five sections for precipitation with zinc. Each box measure 1.5—3 m. The precipitation time is 36 hours and the solution is allowed to pass three times through the boxes and is then brought to an empty tank to be used again in the process.



Conclusions

PEMIN's small plants using the process of amalgamation of gold ores in stamp batteries operate with very poor recoveries, generally below 50 per cent, often considerably lower. Mineralogical and laboratory mineral dressing studies reveal that better results cannot be achieved with the present plant methods, due to the fact that the gold particles are very fine. They are easily lost in slimes, and are not sufficiently liberated in the coarse mineral grains for proper contact with the mercury used in the amalgamation process. The only way of increasing the recovery is to use cyanidation, by which the effective recovery can be increased up to 80—90 per cent, even for treatment of the relatively coarse material from the stamp batteries. Simple forms of gravity separation, for instance sluices, can be used to recover the coarsest gold particles, which require long leaching time. By careful planning it is possible to prevent environment pollution with cyanidation, and thus completely eliminate the present process with amalgamation on copper plate, which causes severe health hazards. Processing plants designed by the Colombian Ministry of Mines and Energy could easily be adapted to the Nicaraguan conditions with the help of Colombian technicians.

However, the first and most important step for an underdeveloped country to increase the recovery of gold resources stemming from small mining activities (alluvial deposits and hard rock operations) is to organize the miners and traders and to offer them prices near the world market as well as technical and social assistance. This method has positively been applied in Nicaragua after the revolution. In this way income from the gold industry will benefit the development of vital economic sectors in a rational economy instead of disappearing in the black market.

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