Laterites - has the time finally come ?

By Alan Taylor*

Sulphides still dominate as a primary source of nickel, but laterites have many points in their favour

After being front runners in the early years of commercial nickel production, laterites were soon overtaken by sulphides as the primary source of nickel. Despite a surge of new laterite operations in the nineteen seventies and early eighties, sulphides still dominate the scene today.

Although still not under serious threat, a combination of current trends and developments may undermine the supremacy of the sulphides and just might tip the balance in favour of laterites for new projects.

Challenges facing sulphides are diminishing grades, increasing mining costs, and growing environmental pressure. Points lining up on the side of laterites include abundant known resources, low mining costs, fewer environmental concerns, and hydrometallurgical processes offering pure products and high cobalt recovery.

Laterites processing today

Four basic process routes are in use at today's laterite operations. They are:

- Ferronickel smelting
- Matte smelting
- Reduction roast - ammonia leach
- High pressure sulphuric acid leach.

A list of current laterite operations, excluding Eastern Europe and the CIS, is shown in Table 1. As a general trend, the older established companies have stuck to pyrometallurgy and ore grades in excess of 1.5% Ni, with ferronickel as the dominant product. It has been largely left to newcomers to embrace hydrometallurgy in an attempt to take advantage of new technology and exploit lower grade resources.

Freeport was undoubtedly the trail blazer pioneering ammonia leaching at Nicaro in 1943 and pressure acid leaching at Moa Bay in 1959. They were followed in the highly active seventies and early eighties by a number of companies which launched major development programmes to improve both of these basic processes. This trend is still evident as interest in laterites is stirring again.

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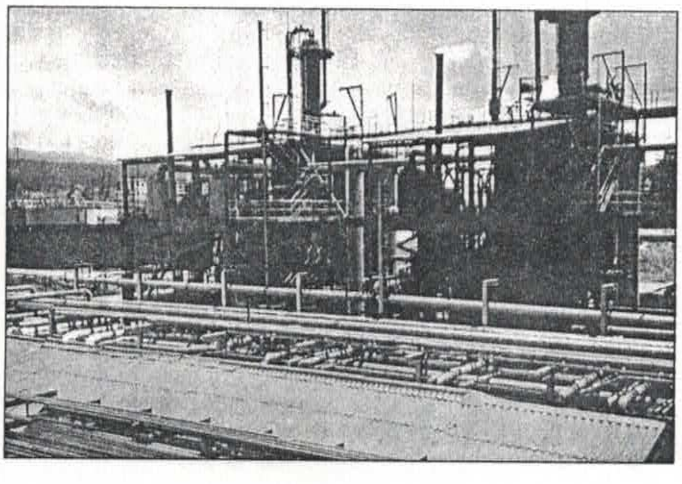
The ammonia leach story

The major players in the ammonia camp were Sherritt Gordon, Freeport themselves, Universal Oil Products (UOP) and the US Bureau of Mines (USBM). The development programme of each group contained the following major objectives:

- Increased metal recoveries by optimisation of reduction conditions.
- Separation of cobalt from the nickel in the ammonia leach solution
- Production of a higher grade nickel product on site.
- Reduction Step



Moa Bay 4th and 5th pressure leach trains.

Table 1 Current Laterite Operations

Ferronickel Smelting	
SLN	New Caledonia
Pamco	Japan
Sumitomo	Japan
Nippon	Japan
Falcondo Dominican	Republic
Cerro Matoso	Colombia
Larco	Greece
Codamin	Brazil
PT Aneka Tambang	Indonesia
Matte Smelting	
SLN	New Caledonia
PT Inco	Indonesia
Ammonia Leaching	
Queensland Nickel	Australia
Nicaro	Cuba
Punta Gorda	Cuba
Tocantins	Brazil
Pressure Acid Leaching	
Moa Bay	Cuba

At Nicaro, reduction is achieved by roasting in the presence of hydrogen and carbon monoxide generated from anthracite coal. The new approaches were:

- Sherritt—reduction with pure hydrogen from naphtha reforming. In another variation, for low iron laterites, pyrite was added to the ore ahead of reduction.
- Freeport—adoption of direct injection of fuel oil as reductant into the ore feed.
- UOP—introduction of additives into the reduction step, including sulphur forms pyrite and H_2S, and halide compounds, usually chlorides.
- USBM—also proposed pyrite addition, but used pure carbon monoxide as reductant.

Cobalt separation

The original Nicaro plant had no cobalt separation step. Cobalt ended up as an unwanted impurity in the nickel product. The proposed improvements in this area were:

- Sherritt—selective precipitation with ammonium sulphide to form Ni/Co sulphide by-product.
- Freeport—Similar to Sherritt except H_2S was used as precipitant.
- UOP/USBM—Separation and recovery of cobalt by solvent extrac-

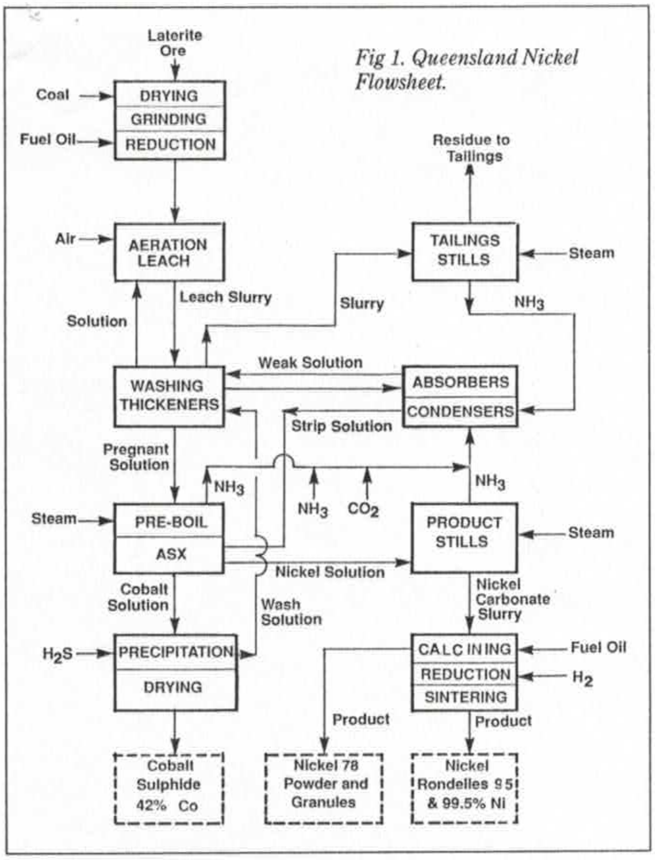


Fig 1. Queensland Nickel Flowsheet.

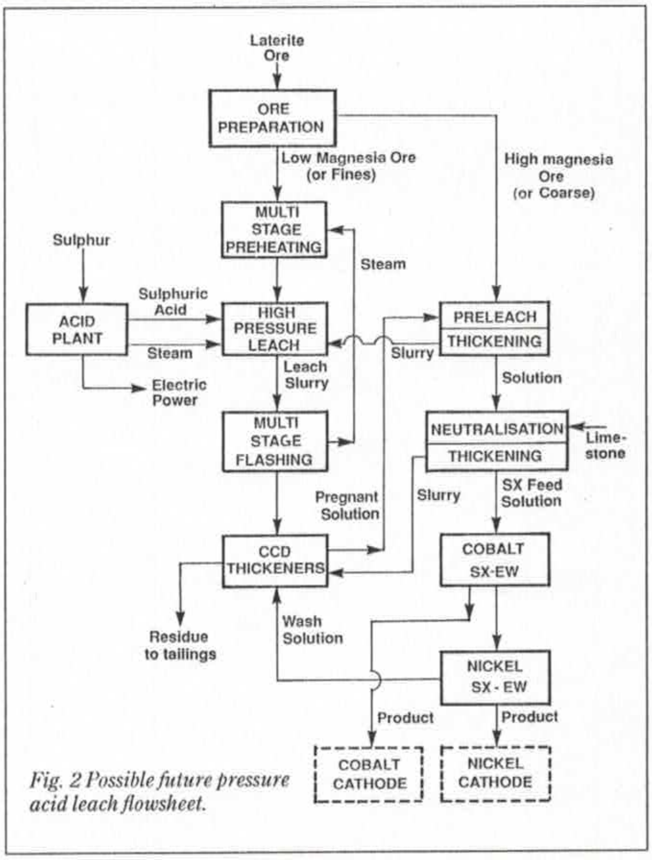


Fig. 2 Possible future pressure acid leach flowsheet.

tion(SX) and electrowinning (EW).

Nicaro initially produced high purity nickel oxide. Later a sintering step was added to cause agglomeration and increase nickel content. The new thrusts were:

- Sherritt—dissolution of the nickel carbonate in ammonium sulphate solution and production of nickel powder by hydrogen reduction at high pressure and temperature.
- Freeport—a similar approach to Nicaro was adopted except that the sintered product was in the form of rondelles.
- UOP/USBM—adoption of solvent extraction/electrowinning (SX/EW) to produce cathode nickel. Both the Sherritt and Freeport developments were commercialised. The Sherritt process was used by Marinduque at its plant on Nonoc Island, Philippines (now closed). Freeport built the Greenvale plant at Yabulu, in Queensland, Australia. The UOP and USBM processes never got beyond the pilot plant stage.

Recent developments

Although laterite activities dropped off dramatically in the eighties and early nineties, significant new developments occurred at Queensland Nickel in Australia and at the Tocantins operation in Brazil. Both of those involved solvent extraction, a technique which had enjoyed growing success for the recovery of copper, uranium, and other metals.

Queensland Nickel pioneered the introduction of a highly selective solvent extraction step to separate nickel from cobalt in the ammonia leach solution. Nickel is extracted by a modified oxime organic, then stripped with strong ammonia-ammonium carbonate solution. The strip solution provides a purified feed for the final nickel recovery steps. After nickel removal, cobalt is precipitated by hydrogen sulphide as before, but the precipitate has a much lower nickel content. The lower contaminant levels increase the value of both nickel and cobalt products and yield significant overall operating cost reductions. The higher grade nickel product in particular increased the percentage of world market available to the company from 60 to 85%. An outline of the current process flowsheet is shown in Figure 1, while a photograph of the SX facilities is shown in the photo on p. 169, courtesy of QNI Limited.

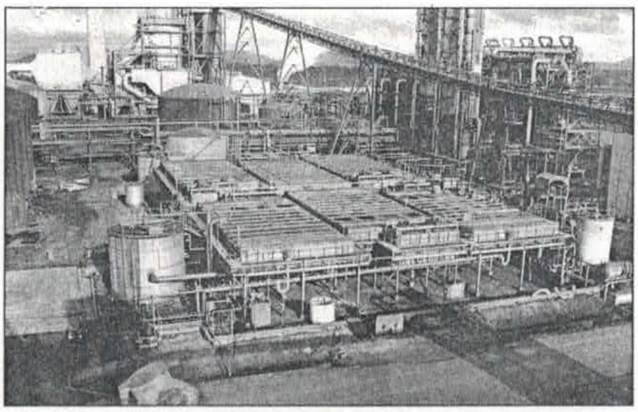
Tocantins' approach was to retain the cobalt in the ammonia leach solution and allow it to co-precipitate with nickel during steam stripping. Using technology originally developed by Outokumpu, the precipitate is then redissolved in acidic spent electrolyte returning from nickel electrowinning. Traces of copper are removed with zinc powder, then soluble zinc is taken out by solvent extraction. Initially, cobalt was to be precipitated with nicklic hydroxide; however another solvent extraction circuit was added to separate cobalt from the nickel, allowing both metals to be recovered by electrowinning.

Pressure acid leaching

While the above groups pursued ammonia leaching, others turned their eyes towards the pressure acid leach process used at Moa Bay. Features which attracted them included very high recoveries of both nickel and cobalt and relatively low energy requirements. The latter feature became all the more alluring as oil costs soared in the seventies. However, the process did have a number of significant drawbacks to overcome. Firstly, as applied at Moa Bay, it appeared to be suitable only for limonitic ores with low magnesia content, in order to avoid excessive acid consumption. Other perceived drawbacks included the highly corrosive conditions in the high pressure leaching step, excessive scale growth in the pressure leach autoclave system, and the mixed nickel/cobalt sulphide product which needed refining.

The next generation

The challenge was taken up in a big way by Amax which launched a major development programme in the seventies, which involved major pilot plant programmes. Improvements claimed by Amax included:



The Greenvale ASX nickel plant in Queensland, Australia.

- Raising the leach temperature to 270°C to achieve faster kinetics and reduce acid consumption.
- Reduction of scale growth in autoclaves by using more than one acid addition point, and enhancing mixing with multi-stage mechanical agitation.
- Significant reduction in energy requirements by incorporating multi-stage flashing of autoclave discharge with recycle of vapour streams to a staged preheating circuit.
- Use of indirect heat exchangers for preheating to improve energy balance.
- Separation of ore feed into high and low magnesia fractions by selective mining or classification, then use of the magnesia rich portion to neutralise residual acid in the leach discharge solution at atmospheric pressure. For some ores, the high magnesia portion required activation by calcination.
- Reduction in scale growth in the H_2S precipitation vessels by recirculating "seed" and operating at lower temperature and pressure.
- Adoption of hydrochloric acid leaching of the mixed nickel/cobalt sulphide precipitate, followed by separation and recovery as oxides or metals by SX techniques.

Amax hailed its "Omnivorous" process as being suitable for the entire typical laterite deposit, including the higher magnesium silicate zones. Unfortunately the opportunity to build a commercial plant at Prony was missed when the project was shelved.

The torch was then picked up by California Nickel which made a sustained but eventually unsuccessful attempt to bring low-grade laterites in northern California into production. Features of its flowsheet included the use of additives to reduce autoclave scale formation, batch instead of continuous pressure leaching, and precipitation of mixed nickel/cobalt hydroxides in place of mixed sulphides. This eliminated the costly and undesirable H_2S precipitation step, and yielded a product readily soluble in ammonia or dilute sulphuric acid with potential for the application of SX/EW.

New contenders

The advent of the nineties has seen renewed interest in the pressure acid leaching route. It has been embraced by a new crop of would-be producers, especially in Australia and the South Pacific region, who have begun to position themselves for the next expected high in the nickel price cycle. Reasons for the rise to favour of the acid leach process include:

- The foundations laid by companies such as Amax and California Nickel.
- Longevity and technical success of the Moa Bay plant.

● Rapid development in commercial scale pressure leaching expertise, equipment, and corrosion resistant materials for the treatment of uranium, zinc, and gold ores.

● Relatively low energy characteristic enhanced by efficient steam and power generation from a sulphur burning acid plant at site.

● Relatively low sulphur and sulphuric acid prices.

● Successful application of SX at the Queensland Nickel plant, and SX/EW at the Nippon and Sumitomo refineries in Japan.

● Development and commercial application of new SX extractants for separating cobalt and nickel in sulphate solutions, such as Cyanex 272 by Cytech.

● Phenomenal growth and success of copper leach/SX/EW operations.

Ultimately, we could be looking at a flowsheet such as that in Figure 2, which promises high metal recoveries, pure products, and highly competitive operating costs.

Moa Bay itself re-emerged to view to non-Socialist eyes by hosting an international seminar in 1991 at Moa, sponsored by the United Nations. This has been followed by the formation of a joint venture company with Sherritt, which includes Sherritt's Fort Saskachewan refinery. The Cubans had planned to pursue further development of the process, including the application of SX/EW. However, the deal with Sherritt has now provided a secure outlet for their mixed sulphide product. A recent photograph of Moa Bay is shown on page. 167, courtesy of Moa Nickel, S.A.

Alternative processes

Apart from the "big four" process routes, there have been many attempts to develop alternative processes. In the sixties and seventies these included:

Nitric acid leaching
Segregation roasting
Sulphidisation, oxidation and cementation-in-pulp (Republic Steel)
Acid pugging and sulphation roast (Sherritt)
Chlorine leaching (Queneau)
Carbonyl extraction (Inco).

For various technical and economic factors none of these progressed past the bench or pilot plant scale.

The renewed interest in laterites in the eighties and nineties has spawned a number of new "hopefuls", as well as a revival of interest in some older ones.

These include:
Atmospheric acid leaching
Heap leaching
Hydrochloric acid leaching
Sulphur dioxide leaching
Submerged lance smelting (Ausmelt)

What next?

The hope of better times ahead for nickel and the advent of high cobalt prices have undoubtedly stirred up interest in new projects. These include existing plant expansions and reopening of mothballed facilities, as well as new grass roots projects for both laterites and sulphides.

The environmental problems facing smelting and the desire of potential new players for mine-to-metal plants, are leading to increased interest in new hydrometallurgical processes for sulphides. These include pressure oxidation and bio-oxidation, encouraged by their commercialisation for the treatment of refractory gold ores.

The key question being asked by many is whether technical advances have finally made the treatment of laterites an economic proposition. This author believes that this is the case, and judging from the rising level of interest, this view is shared by a growing number of enthusiasts.

Time of course will tell, but we could be on the verge of an era when laterites finally begin to fulfil their potential. ❑