The Role of the United Nations

Revolving Fund

in Natural Resources Exploration*

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To follow its early success in finding new mineral deposits in developing countries, the United Nations set up 15 years ago a self-supporting mechanism to expand this record and to help put into production new discoveries of minerals and geothermal energy for the benefit of developing nations. In this candid review, two senior officers of the Revolving Fund describe its aims and activities, which can be likened to an exploration company within the UN. Its objectives complement those of the United Nations Department of Technical Co-operation for Development, described in the companion paper by Guy-Bray and Lewis. The Fund's record is a very enviable one - US\$62 million expenditures for discoveries worth today an estimated \$1.3 billion. The benefits to developing countries seem clear. (Ed.)

The Historical Background

The post-independence period of the 1960s, during which newly independent countries endeavoured to establish their national identities, was followed in the 1970s by a global recession, which had serious impacts on the minerals industry. With the economic climate deteriorating at the same time as these countries wished to receive a greater share of the income from their mineral production, the overall result was a major cutback in exploration activity by the private sector, especially by the international companies that had historically carried out this work.

This situation placed a greater onus on aid organizations such as the United Nations to fill the exploration gap. By the early 1970s the United Nations Development Programme had achieved considerable success in the discovery of major mineral deposits (see accompanying article by Guy-Bray and Lewis), but the need of developing countries for assistance in mineral exploration far exceeded the funds available for traditional UNDP assistance.

As a direct result of the growing awareness by donor governments of the importance of mineral exploration being undertaken in the developing world to ensure the future supply of minerals, and also to assist developing countries to build their mineral and geothermal energy industry, the United Nations Revolving Fund for Natural Resources Exploration was established in 1973. Its operational procedures (United Nations, 1983) were ratified by the UN General Assembly in 1975.

Objectives of the Fund

The fundamental objective of the Revolving Fund is to assist developing countries in the high risk activity of discovering mineral deposits (excluding oil and gas) and geothermal energy, to the point where results are sufficiently attractive and reliable to attract on-going evaluation. The mineral resources sought should be of economic interest (Fig. 1) either domestically or for export. The Fund can also finance feasibility studies on discoveries made in exploration projects that it has already executed. The word "revolving" in the Revolving Fund's name refers to the eventual aim of becoming financially independent by means of receiving a share of the income from discoveries brought into production. This would enable the Fund to continue its exploration activities in other developing countries.

Figure 1: An outcrop of massive sulphides, Camp Coq, Haiti.

* The views expressed here are those of the authors and do not necessarily reflect the views of the United Nations or of the Revolving Fund for Natural Resources Exploration.

Projects are selected on the basis of their technical and economic viability and, thus, their potential to contribute to development of a country. The Fund endeavours to ensure an equitable geographic distribution of projects and, at the same time, to give special consideration to the needs of least developed and landlocked and island developing countries.

An exceptionally important aspect of the Fund's activities is assistance to governments in attracting financial investment for feasibility studies or mine development after completion of the exploration programs. This involves working closely with recipient governments to identify the most favourable option, such as financing feasibility studies by the Fund, co-financing with other governments, international loans, state investment, private initiatives or any combination of these.

An integral part of all Revolving Fund programs is the role played by national staff, the costs of which are borne entirely by the Fund. This involvement in the exploration programs provides the staff with important "hands on" experience (e.g. Fig. 2).

Figure 2: Processing till samples at Ananea. Twin Sweco screens and feeding bins in operation.

What the Fund Does

Projects may be undertaken from the reconnaissance stage through to advanced-level exploration (see Carman, 1979, and Fozzard et al., 1983, for general reviews of the Fund). However, preference is given to the latter in areas for which encouraging information is already available. In this way the exploration risks are reduced, the chances of success increased, and the time to commencement of production reduced.

In carrying out mineral exploration projects a sequence of activities is followed, which begins with preliminary contacts with governments to describe the Fund and its operations and to review the mineral potential of the country and its priorities for commodity development. Upon receipt and preliminary study of an official request from a government offering selected targets, a Fund staff member visits the country concerned to collect more precise data and to make a preliminary assessment.

If the results of the first visit are promising, a consultancy mission is normally mounted to obtain a more detailed opinion on the prospects involved. Provided the consultant's report is encouraging, the Fund prepares and submits to the government concerned a draft proposal containing a work plan and a detailed budget for the first phase. If this proposal is accepted by the government, it is then presented to

the UNDP for approval. The Fund subsequently submits a Project Agreement document, which describes legal and financial obligations and the work program, to be signed by the government and the Fund and ratified by the former.

The next step is to start the field operations described in the project agreement. If the results obtained are encouraging, subsequent work is undertaken to advance exploration to the stage where a deposit with economic potential can be identified. However, if the results are not sufficiently encouraging, the project is terminated when the financial commitment outlined in the project agreement has been met.

The techniques used depend on the nature of the project and may include geological mapping, geochemical and geophysical exploration, pitting, trenching, drilling and underground examinations. The overall sequence is designed to obtain progressively more reliable information on the nature of the deposit, including an estimate of tonnages and grades. Limited beneficiation tests and preliminary assessments of production costs, marketability and profitability may also be made.

At the end of the exploration, whether encouraging or not, a comprehensive final report containing all data collected, conclusions and recommendations for possible further development is submitted to the government, which has full jurisdiction to decide any further action. The conclusion of a successful project leading to the discovery of a deposit can be regarded as equivalent to the completion of a pre-feasibility study and will normally mark the end of the Revolving Fund involvement. In the event that Fund activities do not result in production within thirty years of the signing of the project agreement, Fund expenditures to this stage are considered as a grant to the government.

If further work is carried out by the Fund at the request of the government, this will normally constitute a feasibility study, with the aim of establishing economic viability at a

Figure 3: Steam generation from a productive geothermal well in St. Lucia.

higher confidence level. This phase will generally involve obtaining more precise information on grade and tonnage, mineralogy, mineral processing procedures, recovery rate, mining methods and other aspects needed to estimate production costs so as to assess potential profitability. The expenses of the feasibility study are considered a reimbursable loan, irrespective of whether production follows.

In the case of geothermal exploration, the aim is to discover high enthalpy sources capable of power generation, thermal energy production, or both (Fig. 3). Here the Fund may involve geological, geochemical and geophysical surveys of promising areas, leading to the drilling of exploration holes or wells. The data from these will help to determine the existence of a reservoir, its physical and chemical characteristics and its productivity, and to estimate the possible reserves of the field. This would normally represent the last phase of a successful project but, as in the case of minerals, the Fund may finance a further feasibility study. This can involve production well drilling and testing to demonstrate the presence of sufficient fluid for production tests, as well as encrustation and corrosion studies, and the assessment of multi-purpose utilization, fluid processing, transport and disposal.

Figure 4: The Ananea project area in the high Andes of Peru at an elevation of 5,000 m. Looking over the dump from a small gold mine towards a previously glaciated area of gold-bearing till.

The Project Record of the Fund

To the end of 1987, the Fund had expended \$62 million (1987 dollars) on 23 projects, resulting in the discovery of a variety of deposits with an in-ground value in the order of \$1.3 billion. These include potentially economic deposits in Argentina (gold and silver), Benin (kaolinite), Congo (shell/phosphate), Ecuador (silver, zinc, lead and gold), Haiti (gold), Honduras (silver and gold), Peru (gold) and Suriname (gold). In addition geothermal energy has been located on St. Lucia in the Caribbean.

One of the most spectacular successes involves exploration for gold in glacial overburden in the Ananea area of south-eastern Peru. The results here indicate the presence of $250 \times 10^6 \text{ m}^3$ of material containing 200 mg/m^3 of recoverable gold worth over \$725 million, based on a gold price of \$450 per ounce. The gold is in glacial till derived by erosion from a local bedrock source that has been mined on a small scale for many centuries (Fig. 4). The area includes one previously dredged by an American company and a small zone currently being worked by Minero Peru. However, the results indicate gold-bearing material to be much more extensive than previously recognized.

Preliminary stages of the program here involved a resistivity survey (contracted to the British Geological Survey) to determine the thickness of the glacial overburden. This indicated the till to be commonly 40-60 m thick and up to 100 m in places. A variety of other glacial deposits within the area was also indicated, and subsequent mapping of the glacial stratigraphy (undertaken on contract by a Finnish expert) identified the presence of two different tills that had been transported in different directions.

Pitting and 11,200 m of drilling by a Chilean company (Figs. 5, 6) were then carried out to establish the gold contents, and heavy mineral concentrates were analyzed locally for their recoverable gold content by Peruvian personnel (see Fig. 2). Up to 3,000 m of additional drilling is now scheduled, together with extensive pilot testing. If the deposit proves to be economic, it is envisaged that mining will be undertaken by dredging (Fig. 7) comparable to that used in neighboring Bolivia.

Another significant discovery by the Fund has involved the identification of over 32×10^6 tonnes of shell and phosphates offshore of the Congo, with an estimated value of about \$250 million. The occurrence of phosphate in the region was first recognized by a team from the University of Brazzaville. On the basis of these indications, the Revolving Fund undertook an exploration program to identify the extent and grade of the phosphate deposits over a 360 km^2 area. The investigations included a combination of seismic profiling, side-looking sonar, vibro-coring, gravity coring and dredge sampling.

Subsequently, agricultural tests on bulk samples were carried out, by a team from the U.S.A. to establish the benefits of direct application of the pulverized phosphate/shell mix on peanut and corn (maize) yields. These resulted in yield increases of 41% and 73% respectively. Tests indicate that the application of the crushed shell material rapidly increases soil pH to desirable levels for plant growth and maintains these levels over two growth cycles. The additions also reduce toxic aluminum and manganese, as well as effectively providing the essential calcium and phosphorus in large amounts and other plant nutrients in lesser amounts.

The deposits indicated to date amount to 7×10^6 tonnes of phosphate (around 30% P_2O_5) and 25.5×10^6 tonnes of shells at water depths of 30 to 50 m some 20 km from the coast. The economic viability of the deposits as a source of fertilizer and cement will be determined by a feasibility study now scheduled with financial assistance from France.

A very recent success of the Fund has been the identification of potentially significant geothermal energy on the island of St. Lucia in the Caribbean (see Fig. 3). Earlier

Figure 5: Sampling till with a drill rig, Ananea, Peru.

work undertaken by British agencies involving geophysics and drilling revealed temperatures up to 220°C but failed to identify permeable zones. Subsequently, work was undertaken by Aquater of Italy involving geophysics, geochemistry and geology, and later by Los Alamos of the U.S.A.

In 1986, the Revolving Fund, together with assistance from the U.S.A. and the Government of St. Lucia, commenced a drilling program. The first hole drilled to 2334 m encountered temperatures of 262°C but lacked permeability. However, the second well, located in the same area as previously drilled by the British but to greater depths, intersected temperatures of 290°C with a bottom pressure of 80 bars and good permeability. Enthalpy was found in the range 2800-1900 kJ/kg in the zone of superheated steam, with a mass flow of 36-40 tonnes/hour. Preliminary estimates of the potential capability for power generation are in the order of 5 MW, which compares to a total island consumption of 12.5 MW. This discovery promises to make a very significant contribution to St. Lucia's energy supplies, now entirely dependent on imported fuel.

Figure 6: Unloading equipment for pulling casing at Ananea, Peru.

With few exceptions, the average expense per project has been approximately \$3 million, of which \$1 million has been spent on the minimum work commitment required in the project agreement and up to two thirds for subsequent operations. Co-financing up to 50% and more of the total expenditures forecast has been arranged with donor countries, and this formula will be expanded whenever possible in order to implement more projects.

In addition to its continuing involvement in the Peru and St. Lucia projects, the Fund is now working on silver, gold and base metals in Honduras, and gold projects are underway in Côte d'Ivoire (Ivory Coast), Rwanda and, most recently,

Figure 7: Abandoned dredge used in earlier gold mining, Ananea, Peru.

Ghana. The latter is of particular significance because the project area is only some 3.7 km² in area, is located 5 km from an existing mine and is known to contain some 3 x 10⁶ tonnes grading over 5 g/t gold. A project agreement has recently been signed to explore for metallurgical grade chromite in the Philippines.

Replenishment Contributions

To date the Revolving Fund has obtained its financial base in the form of contributions from certain donor countries that share the risks involved. As mentioned previously, the long term objective is for the Fund to become self supporting through payments from production resulting from the successful projects. The proceeds would then be reinvested in further exploration in developing countries, thereby creating a mechanism for mutual assistance and cooperation among developing countries.

Replenishment Contributions for mineral exploration projects will be levied at the uniform rate of 2% of the annual value of produced commodities (1% for countries designated by the UN as least developed) for a period of 15 years from the start of commercial production, or until a ceiling of 10 times total project costs at constant prices is attained. For geothermal energy projects the Replenishment Contribution is 5% of the fair market value of the energy produced for a period of 15 years or until a ceiling of three times total project costs at constant prices is attained. The higher replenishment payments for geothermal energy projects reflect the lower risks involved.

The 15-year period is counted from the commencement of commercial production and will be automatically suspended for periods of non-production and extended accordingly. Where economically marginal projects are prevented from coming into production by the Replenishment Contribution, the Government and the Fund may agree to a lower percentage over a period longer than 15 years or to a lower contribution for part of this period followed by a higher percentage for the rest.

Assessment of Replenishment Conditions

The basis for establishing the replenishment terms of the Fund was the exploration success of the UNDP. From 78 projects before 1973 at a cost of \$84.5 million, 11 deposits were identified, with a total value of \$32,712 million (based on 1974 metal prices). These were mainly porphyry copper and iron deposits that are typically extremely large, high value deposits with a long mine life and, because of their size, relatively inexpensive to identify.

Since 1973, the mineral commodities of economic interest in the mining industry have changed dramatically, and of these 11 deposits at least four, worth \$11,883 million, have remained undeveloped for economic and political reasons. The major worldwide focus of exploration activity is now centered on gold deposits. These are quite different in terms of size, value and mine life from the porphyry copper and iron deposits on which the replenishment formula was based, and therefore different conditions would be applicable.

This feature can be illustrated by an analysis of 136 gold deposits discovered in Canada in the period 1946-1985. The information on these constitute a data set of reasonable size, and the basic characteristics of gold deposits are considered to be broadly comparable throughout the world. The mine life of the Canadian deposits varies from 3-28 years with a median of 7 and an average of 8.6 years. The total revenue, based on a gold price of \$450/oz, varies from a low of \$8.8 million to a high of \$4,222 M, with a median of \$95 M and an average of \$228 M for a grand total of \$31,068 million (Fig. 8). The considerable discrepancy between the median and average values is due to the very skewed distribution in the total revenue of the 136 deposits.

To achieve a return to the Fund, assuming an average exploration cost of \$3 million and a 2% replenishment rate, the total revenue from a deposit must be \$150 million. The data distribution in Figure 8 shows that 75% of the deposits have values of less than \$150 million. Furthermore, only three have values in excess of the \$1500 million necessary to provide replenishment up to the ceiling of ten times the exploration cost. On the assumption that all deposits are economic, the total value subject to replenishment is \$27,102 million, giving a total replenishment of \$542 million.

However, at a gold price of \$450/oz, only about 100 (74%) of the 136 deposits would be economic, thus lowering the potential replenishment to \$402 million. Indeed the sixth most valuable gold deposit found in Canada, with a contained gold value of \$1,036 million, is uneconomic at a gold price of \$450/oz. The high proportion of the total revenue attributable to a very small number of extremely large deposits is further highlighted in Figure 9. A single deposit (A) yields 13.6% of the total revenue, 27% comes from three (A, B and C), and 51% from the ten largest (A to J) deposits.

Furthermore, to reach the ceiling of ten times exploration costs requires the necessary production within fifteen years. In most cases, the very large deposits have a mine life considerably longer than fifteen years. Therefore, the limiting factor on replenishment in these cases would be fifteen years rather than ten times exploration costs. This indicates the very small chance of the latter ceiling ever being applied.

Figure 8: Frequency distribution of 136 Canadian gold deposits discovered between 1946 and 1985. The deposits labelled are keyed to Figure 9: off the scale are deposits A (value \$4222 million) and B (value \$2500 million).

Figure 9: Cumulative curve showing the relation between total revenue and number of deposits for 136 gold discoveries in Canada in the period 1946-1985.

With an average project expenditure of \$3 million, exploration costs for the 136 Canadian gold deposits would amount to an exploration expenditure of \$408 million. This analysis, it should be remembered, is based on exploration successes and takes no account of exploration programs that failed to discover a mineral deposit. Assuming a success rate of one in ten, some 1360 exploration projects costing \$4080 million would have to be carried out in order to discover 136 deposits. Moreover, most financial analysts regard a gold price of \$450/oz as too optimistic for the 1990s. If so, the replenishment payments would be expected to be smaller.

On the above basis, it appears that for gold deposits the present replenishment formula is not adequate to allow the Fund to achieve financial independence and to revolve. Yet from the developing country's viewpoint, utilization of Fund facilities is highly attractive because costs are borne by the Fund except

where a discovery comes into production. This situation compares very favourably with other development assistance agencies where the recipient government bears the costs of national personnel or, in the case of loans, repays these irrespective of the outcome of the program. Even in the case of production resulting from a Fund exploration program, the cost to the developing country is small, and in most cases not even the exploration expenditures incurred by the Fund will have to be repaid.

If, for example, the Peruvian gold deposit described above proves to be economic, assuming an annual production of $3.5 \times 10^6 \text{ m}^3$, this would produce $7 \times 10^5 \text{ g}$ gold annually. The total replenishment over 15 years could thus be \$3 million, compared to actual project expenditures of approximately \$5 million. For the St. Lucia geothermal project, assuming a productivity of 5 MW, the annual value of energy produced would be \$1.8 million. At 5% this would generate a return to the Fund of \$1.35 million over fifteen years, compared to actual Fund expenditures of \$3.4 million.

Despite the expectation that the Fund will receive its first replenishment in 1988 from a project in Ecuador begun less than 12 years ago, it seems that the Fund will, in all probability, never revolve. However, this is not perhaps of great importance. The more significant factor is that the Fund continues to be successful in finding orebodies and geothermal energy sources for the benefit of the developing world. Its existence is, therefore, surely fully justified.

Assessing the Fund's Performance

Since its inception, various factors have hampered the Fund's activities. The most important appears to have been the reluctance of governments to permit the Fund to explore in very attractive areas, basically because of the perceived high cost of the replenishment component. This has caused the Fund to begin work in some cases at a reconnaissance level, which inevitably involves higher risks. Even assuming success, such projects involve a longer time period between the start-up of exploration and commencement of production. This situation is considered to be against the interests of developing countries.

A further problem has been that the Fund has operated on a smaller scale than originally envisaged. One early prediction (Dhrymes, 1974) was that the Fund would require total contributions of \$200 million in 1974 dollars (equivalent to about \$400 million in 1987 dollars) in order to achieve financial independence and to revolve after twenty years of activity.

Both the Fund and host governments have also had difficulties in attracting finances for on-going evaluation of successful projects. Among other reasons for this are the down-turn in international mineral exploration due to economic factors, political uncertainties, and the lack of agreement between potential investors and host governments. Nevertheless, in its relatively short lifetime, the Fund has achieved an enviable success rate, in terms of its exploration budget and the in-ground value of deposits discovered. This performance can only be to the benefit of developing countries.

The Fund is acutely interested in expanding the range of mineral commodities with which it is currently involved, and in extending the geographic distribution of activities, especially in Asia where it has so far been inactive. Current projects under consideration are in China (pyrophyllite) and Sri Lanka (heavy mineral beach sands). In addition, the Fund has recently completed a review of possible future projects in the SADCC (Southern African Development Coordination Conference) countries of Angola, Botswana, Lesotho, Malawi, Mozambique, Swaziland, Tanzania, Zambia and Zimbabwe, where the collective aim is to reduce dependence on the Republic of South Africa.

A similar assessment is also underway for Central America, and the Fund is also carrying out a study to identify a development strategy for geothermal energy resources in developing countries. Developing countries are now displaying a markedly increased interest in utilizing the services available, and the Fund welcomes requests from governments to consider undertaking attractive exploration projects.

The Fund will only be able to maintain an active role in exploration in the developing world if it obtains increased contributions from the donor community to generate a minimum income of \$10 million annually. Continued and stronger support is required from the industrialized nations in particular, for they have a vital global interest in mining development and in the diversification of sources of supply for important minerals. The Fund provides a vehicle for working together for the future for natural resource exploration and development and for strengthening the bond between industrialized and developing nations.

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