ENVIRONMENTAL MANAGEMENT FOR LIMESTONE QUARRIES IN JAPAN

Hisakazu Oguri, Hiroshi Kaburaki, Kenji Moriyama[1]

Abstract.--In Japan, most limestone is obtained by surface mining. At Nihon Cement's Garo Quarry (capacity 500,000mt/mo) in Hokkaido, special measures for environmental management (accounting for approximately 9.8% of operating costs), such as a bank encircling the working face, stratified piling in the dump, water control, and revegetation have been adopted. The quarry continues to operate smoothly without pollution problems. Trees growing just outside the bank are not felled immediately to protect the scenic beauty; runoff is prevented from flowing outward by the bank. One-meter layers of waste in the disposal dump are well compacted. The dump is divided into several separate sectors, with disposal carried out on a rotating basis; grass is temporarily planted in idle sectors. Generation of polluted water is minimized. Polluted water is collected and led to precipitation ponds via hillside ditches and surface conduits; after filtration and sedimentation, water is discharged to the river. In the dump, revegetation is carried out in the completely filled sectors by first sowing grasses, i.e. Kentucky 31 fescue (Festuca elatior var. Arundinacea WIMM.), white clover (Trifolium repens LINN.), and/or redtop grass (Agrostis alba LINN.), and then by planting saplings such as wild black alder (Alnus japonica) and white birch (Betula tauschii) on plane steps. The step revegetation, wall-hole, and frame and sprayed soil-and-seed methods are used for slope revegetation in other quarries in Japan; at Osaka Cement's Ibuki Quarry, transplantation of the originally existing plants has been introduced. Environmental management is one of our foremost concerns and we must do our utmost to prevent our activities from resulting in environmental pollution.

INTRODUCTION

In Japan, all enterprises are strictly required to coordinate their industrial development and operation with conservation of the natural environment. The development and operation of limestone quarries is no exception. There are several peculiarities related to the locations of mines and the carrying out of related environmental controls on mining activities. Japan is a small, but highly industrialized, densely populated country where agriculture is still important. Because

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Table 1.--Annual production of Japan's 104 main limestone quarries. (in thousands of metric tons)

Year	Surface mining Prod.	Pct.	Underground mining Prod.	Pct.	Total
1985	140,267	99.5	689	0.5	140,996
1986	133,332	99.4	686	0.6	134,996
1987	130,856	99.4	807	0.6	131,663

of its complex geological situation, many types of ore deposits are found and mined there, and many of these deposits are near populated areas. In addition, most of the limestone quarries in Japan use the surface mining method (table 1), and many quarries are located near scenic spots. Therefore, our exploitation of limestone must be carefully balanced with conservation of nature through such methods as revegetation of quarried areas.

The existence of vegetation and forests is fundamental to human life; these resources exert controls on the population by affecting the water in rivers and preventing soil erosion, as well as by being natural air cleaners. Of course, the emotional effects such as improving the appearance of the surroundings are also important. On the other hand, it must be recognized that utilization of the world's finite mineral resources is just as necessary to society as is the reasonable growth of industry. Conservation of the natural environment involves a wide range of problems. Since surface mining causes changes in the environment, industrial projects must be coordinated with conservation efforts.

DEVELOPMENT OF GARO LIMESTONE QUARRY

Location and Climatic Conditions

Garo Quarry is located 7km northwest of NCC's (Nihon Cement Co., Ltd.) Kamiiso Plant, which is 10km west of Hakodate City, a major port on Japan's northernmost island, Hokkaido (figure 1).

Climatic conditions at Garo Quarry are shown in table 2.

Table 2.--Climatic conditions at Garo Quarry.

Item	Remarks
Average Temp.	8°C (46.4°F)
Maximum Temp.	33°C (91.4°F)
Minimum Temp.	-18°C (-0.4°F)
Rainfall	1,160mm
Snow (Nov. to Mar.)	About 3m deep

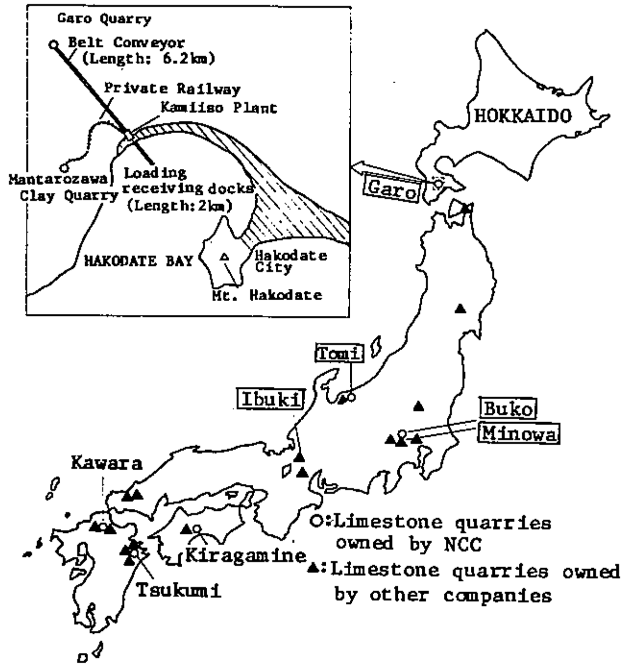

Figure 1.--Location of Garo Quarry.

Geology

The structure of Garo limestone deposit is shown in figure 2.

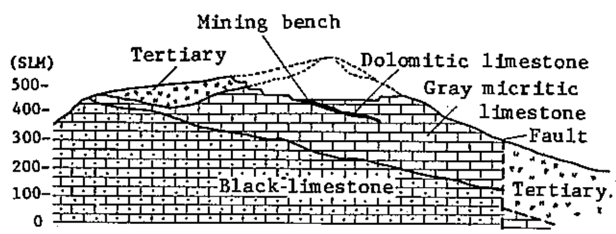

Figure 2.--Section of Garo limestone deposit.

The limestone deposit, consisting of massive distributions of gray micritic and black mesozoic limestone with intercalations of dolomitic limestone, is an anticlinal dome shape partially disturbed by folding and faulting. The tertiary formation which widely overlays the limestone deposit to a maximum thickness of 70m consists of well-stratified basic conglomerate, mudstone, and tuffaceous sandstone.

Basic Development Concept

Garo Quarry was opened in 1890 to supply limestone for cement to the Kamiiso Plant. As the plant expanded its

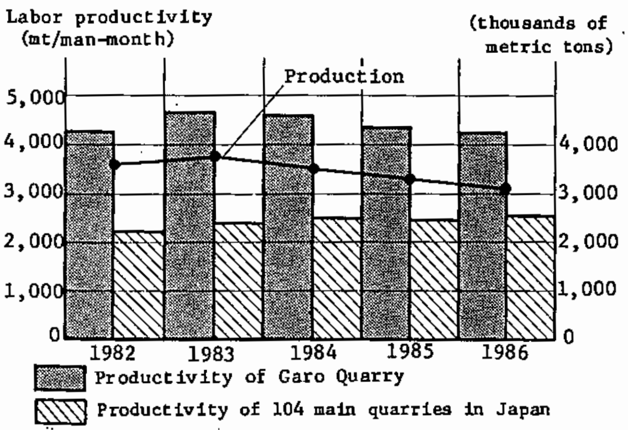

Figure 3.--Limestone productivity (1982-1986).

level of production, the quarry kept pace. Development of the new Hekirichi area was begun in July 1974, and practical operation started in January 1978. The Garo Quarry project was undertaken with several basic development concepts in mind, including: a monthly limestone production capacity of 500,000mt, achievement of high productivity (figure 3), prevention of pollution, and coordination with the surrounding natural environment.

ENVIRONMENTAL MANAGEMENT MEASURES

Bank Encircling Quarry Bench

A bank (guard wall) 5 to 10m high is formed around the quarry, making it virtually impossible to see the quarry from the outside. Trees growing just outside the bank are not felled until immediately before it is levelled (figure 4) in order to protect the scenic beauty. In addition, the bank, inside which rain and melted snow evaporate, serves to prevent river pollution due to runoff.

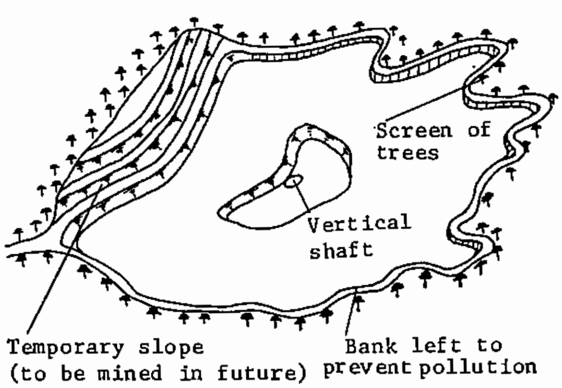

Figure 4.--Quarrying method.

Overburden Disposal Dump

The overburden disposal dump is designed to meet government construction standards. It has a capacity of 15 million mt (7.9 million m^3) and will cover an area of 23.8ha (58.8 acres) and reach a height of 450m above sea level in the future. Based on our experience, the following measures have been adopted: one-meter layers of waste are compacted with a compacting roller, thus reducing them to about 80% of their original volume (figure 5); the disposal dump is divided into three or four separate sectors, with disposal carried out on a rotating basis; in dump sectors not in immediate use, temporary ditches for runoff are dug, covered with vinyl sheeting to prevent surface collapse, and temporarily planted with grass; vegetation is planted and seeds sprayed in the completely filled sectors (figures 5 and 6). Approximately 9.5 million mt of overburden have been stripped and 28 million mt of limestone produced. The quarry continues to operate smoothly without pollution problems, and pollution prevention is seen as successful.

Water Control

The water control system at the Garo Quarry is shown in figure 7. At the Hekirichi working face, runoff is led to the lowest bench via the natural slope and the face-connecting road for evaporation. Water is prevented from flowing outward by the bank encircling the bench. In the Garo overburden disposal dump, generation of polluted water is minimized by the use of sectional stratified piling and temporary and standard revegetation procedures. Polluted water is collected and led to precipitation ponds via surface conduits, temporary surface ditches, and underground conduits. Spring water, rainwater that is from undeveloped areas or from near the disposal area, and polluted water from the mine road are collected via hillside drainage ditches and led to the precipitation ponds.

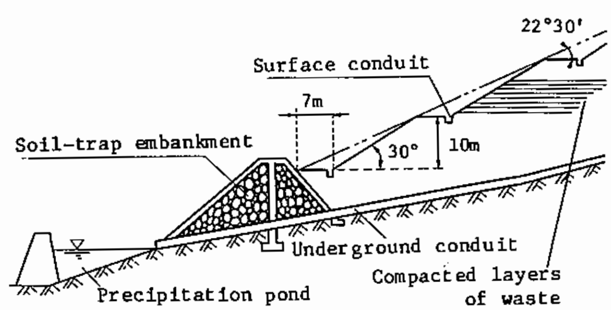

Figure 5.--Cross-section of overburden dump.

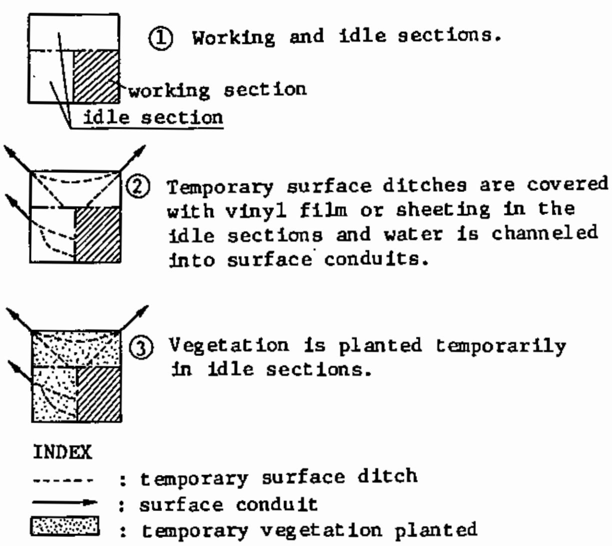

Figure 6.--Sectional stratified piling method.

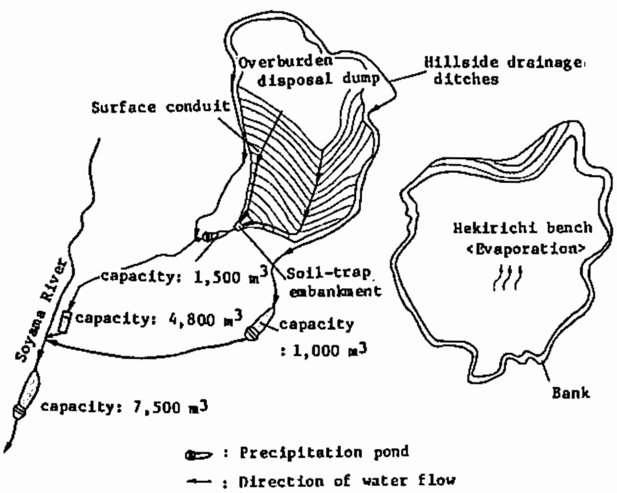

Figure 7.--Water control system.

Water is discharged to the river after filtration and sedimentation. Precipitation ponds are wide and shallow to allow for easy dredging.

Revegetation

The final goal of revegetation is to return the natural environment to the state that existed in the local area before development. Reforestation is impossible in a short period of time, and conditions worsen with continuing operations; therefore, the short-term aim of revegetation must be primarily to replant the basic vegetation to promote long-term natural restoration of the environment.

Sowing of grass seed and planting of saplings in the overburden disposal dump at Garo Quarry are carried out in sections in the order in which piling is completed.

First, Kentucky 31 fescue (Festuca elatior var. Arundinacea WIMM.), white clover (Trifolium repens LINN.), and/or redtop grass (Agrostis alba LINN.) are sown. After preventing surface collapse with rapidly growing grasses, saplings such as wild black alder (Alnus japonica), white birch (Betula tauschii), white fir (Abies concolor), and wild cherry (Prunus serotina) are planted on plane steps. Recent data on revegetation at the dump is shown in table 3.

At Mantarozawa Quarry, which supplies clay material for the Kamiiso Plant, successful revegetation of the quarried area, primarily with wild black alder, but also with some white birch and larch (Larix) saplings, has been carried out since 1982 (table 4). The layout of Mantarozawa Quarry is shown in figure 8.

As there is little data on final slope revegetation at Garo Quarry because of limited experience, actual examples of final slope revegetation at other limestone quarries in Japan are substituted.

Ibuki Quarry (Osaka Cement Co., Ltd.), famous in Japan for its pioneering revegetation procedures, was developed in

Table 3.--Revegetation at Garo disposal dump.

Year	Area sown (m^2)	Temporary area sown (m^2)	No. of saplings planted
Pre-1984	62,000	329,000	9,630
1984	16,000	81,000	1,100
1985	16,600	85,600	1,070
1986	13,400	48,000	1,050
1987	15,500	44,000	1,200
Total	123,500	587,600	14,050

Table 4.--Revegetation at Mantarozawa Quarry since 1982.

Year	Revegetated area (m^2)	No. of saplings	Reforested area (m^2)[1]
1982	18,759	5,400	32,068
1983	20,436	4,590	
1984	7,710	2,570	----
1985	2,650	875	----
1986	500	190	10,332
1987	1,200	300	----
Total	51,255	14,285	42,400

[1]Area approved by government agencies.

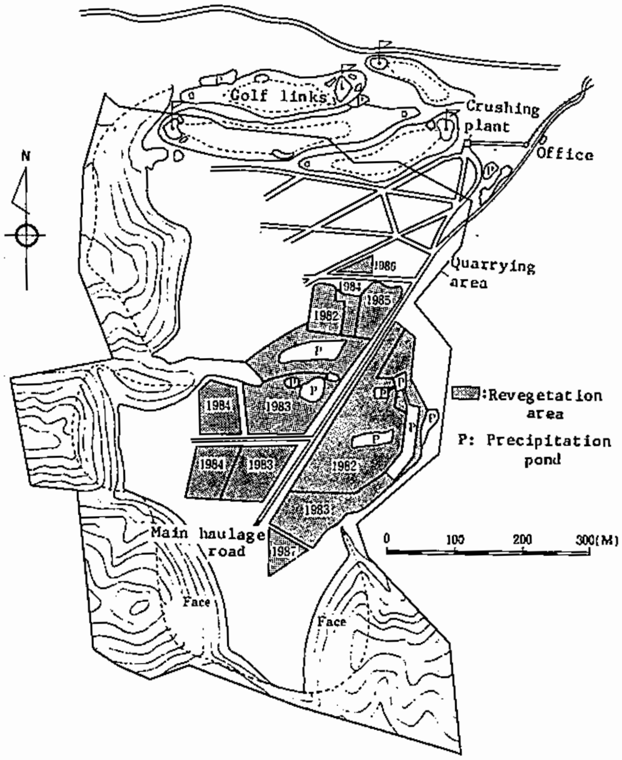

Figure 8.--Layout of Mantarozawa Quarry.

1951 to supply limestone to Ibuki Cement Plant (current limestone supply capacity: 350,000mt/mo). Various procedures were tried; the eventual method of slope revegetation mainly consists of transplanting the originally existing plants. The procedure is as follows: original vegetation is investigated; the bench is prepared; surface soil is transported; a fence to prevent snowslides is constructed; the originally existing plants are transplanted, and the area watered and fertilized; seeds are then collected and pre-grown in a nursery; finally, the revegetation is reinvestigated and the cycle begins again from preparation of the bench. The revegetated area of the quarry totals $305,000m^2$ to date (table 5), and the results have been widely acclaimed.

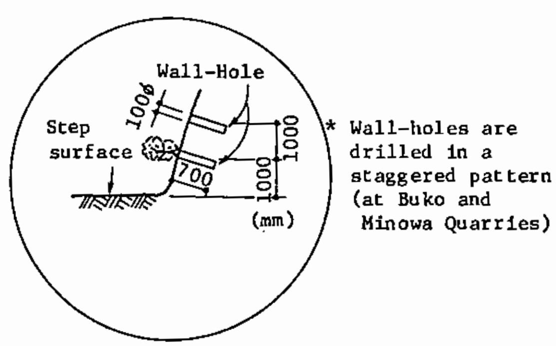

Figure 9.--Standard wall-hole revegetation method.

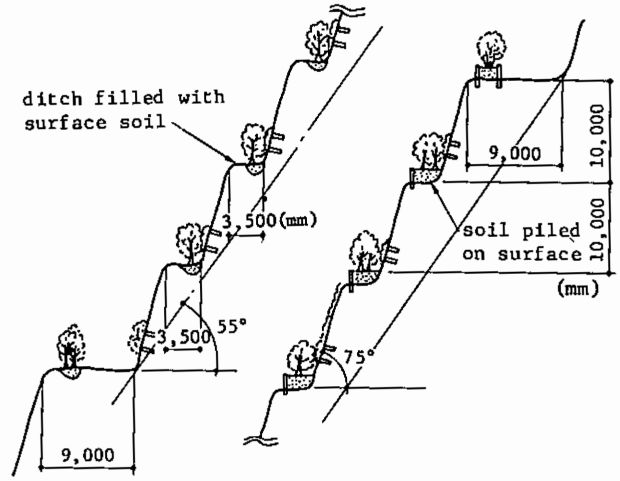

Figure 10.--Standard step revegetation method (at Buko and Minowa Quarries).

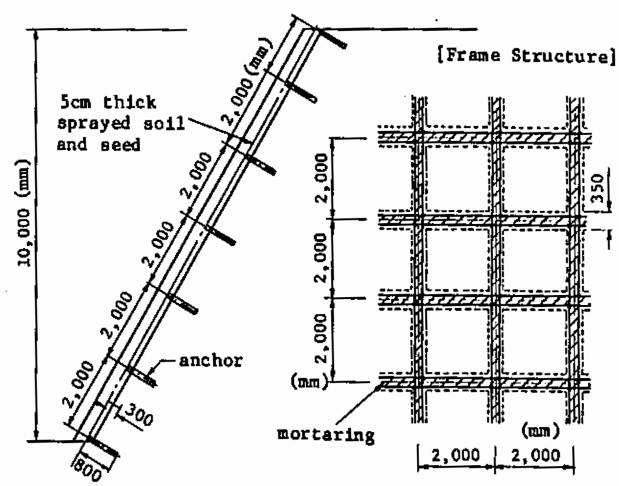

Figure 11.--Standard frame and sprayed soil-and-seed method (at Tomi Quarry).

Table 5.--Revegetation at Ibuki Quarry since 1971.

Year	Revegetated area (m^2)	Transplanting (m^2)	Other methods (m^2)
1971-80	206,890	139,990	66,900
1981	15,050	15,050	----
1982	12,000	12,000	----
1983	12,630	12,630	----
1984	18,330	18,330	----
1985	16,410	16,410	----
1986	23,678	23,678	----
Total	304,988	238,088	66,900

OPERATING COSTS

A breakdown of limestone production costs by percentage for Garo Quarry is shown in table 6.

Table 6 shows that special measures such as stripping and stratified piling, introduced to protect the natural environment, represent 9.8% of the raw-material production costs, a rather substantial increase over quarrying costs without environmental protection measures.

In general, achievement of low-cost operation is the fundamental goal of private enterprise. Efforts to achieve low-cost operation must include environmental protection measures through improvement of stripping and piling procedures, revegetation procedures, and the possible use of overburden piled in the dump as a material for cement, with the aim of turning expenditure into income. No goal can be achieved without technology.

If any unexpected damage or pollution problem occurs, the enterprise is inevitably held responsible. Compensation and fines in these cases are often in excess of the enterprise's ability to pay immediately. Heavy financial losses due to shutdown of operations may also result. Therefore, active investment for the purpose of conserving the natural environment should be understood as being more economical in the long run than the carrying out of mining from the viewpoint of cheaper production alone.

Table 6.--Breakdown of limestone production costs at Garo Quarry.

Item	Pct.	Remarks
VARIABLE COSTS		
Explosives	5.7	ANFO, electric detonators, etc.
Fuel & lubricant	4.8	
Electric power	2.5	Includes private power generation
Stripping & piling	9.8	Special conservation measures
Miscellaneous	0.5	Municipal taxes, etc.
Subtotal	23.3	
FIXED COSTS		
Supply & maintenance	18.8	
Labor	28.6	Includes regular contractors
Depreciation	22.4	
Overhead	6.9	Government taxes, etc.
Subtotal	76.7	
Total	100.0	

CONCLUSION

Environmental management is one of the foremost concerns at Japanese limestone quarries, and is an extremely important technical problem for engineers engaged in mining operations. In this paper, the development and operation of NCC's Garo Quarry has served as a typical example of how an industrial project can be coordinated with the natural environment through the adoption of special measures such as sectional stratified piling in the overburden disposal dump, water control, and revegetation. Examples of revegetation procedures used for quarried areas and final slope at other quarries in Japan are also described. Although introduction of special environmental protection measures does result in increased raw-material production costs, active investment for the purpose of conserving nature should be understood as being more economical in the long run; achievement of low-cost operation, a fundamental goal of private enterprise, cannot be realized without advanced technology. The future of natural resources depends on willingness to pay the price and take the steps necessary to protect the environment.