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SOUTH WEST AFRICA
SUIDWES-AFRIKA

THE MARBLE DEPOSITS OF SOUTH WEST AFRICA

BY H. R. PORADA AND R. S. HILL

MET 'N OPSOMMING IN AFRIKAANS ONDER DIE OPSKRIF:

DIE MARMERAFSETTINGS VAN SUIDWES-AFRIKA

REPUBLIC OF SOUTH AFRICA, DEPARTMENT OF MINES
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by

H. R. Porada, Dr. rer. nat. and R. S. Hill, M.Sc.

Met 'n opsomming in Afrikaans onder die opskrif:

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THE MARBLE DEPOSITS OF SOUTH WEST AFRICA

ABSTRACT

Marble occurs in several geological units in South West Africa, notably in the Swakop and Nama Groups. The present investigation was conducted with a view of determining the suitability of the deposits for dimension stone quarrying and for that reason those situated within a reasonable distance from the main traffic arteries received most attention.

Near Karibib large reserves of white, reddish, brownish and grey marbles of the Swakop Group are present, the rocks being either unicoloured, strikingly banded and folded, or flamed (intraformational breccias). Coloured and variously patterned varieties as well as consolidated collapse breccias are mainly found .in the Dernburg Range where several quarries were established before World War I, while blocks of white marble were formerly quarried on Navachab 58, on Mon Repos and at the Karibib "Town Quarry". At present the Karibib marbles are being worked only on a limited scale for the manufacture of table-tops, tombstones and various ornaments, as well as for the production of marble crush which is used for terrazzo and marble roughcast.

The major problem hampering the production of marketable marble blocks is the generally severe jointing which affects many otherwise promising deposits. In addition, solution fissures and cavities, which locally may reach considerable depths, may detract from the value of some occurrences. It was also found that with prolonged exposure certain banded varieties develop a tendency to split along the banding, while many white varieties tend to "sugar".

Tests conducted on a number of borehole core samples from Karibib by the National Building Research Institute of the CSIR in Pretoria proved that they had .a very low water absorption capacity and an adequate compressive strength. However, the way in which samples of certain varieties "sugared" under high compression, render these marbles suspect for exterior use.

East of Swakopmund and southeast of Walvis Bay a greenish serpentinebearing marble appears to be the only variety which is suitable for exploitation as dimension stone. It crops out in long narrow bands, but is best developed about 15 km east of Swakopmund. It is being worked sporadically on a small scale for decorative and ornamental purposes.

South of Windhoek white marble is produced on a small scale on Gocheganas 26 for the manufacture of terrazzo and marble roughcast. At Lübbertberg, about 80 km southeast of Windhoek, large reserves of coloured marbles are present. The bulk of the marble in this area, however, is intensely sheared and strongly contaminated by impurities.

Other occurrences which were also inspected are either too poor in quality (northwest of Otjiwarongo), occur in too small quantities or are too far away from main roads and railways (west of Rehoboth and east of Lüderitz) to be considered as exploitable under present circumstances.

It can be concluded that, from a geological point of view, certain varieties of marble in the vicinity of Karibib, Swakopmund and to a lesser extent Windhoek, appear to be suitable for dimension stone quarrying. However, it will be economic aspects such as a steady demand and quarrying and transport costs that will determine whether these marbles could be exploited profitably or not.

I. INTRODUCTION

A. GENERAL

Marble deposits of considerable extent are found in a number of geological units in South West Africa. Within the pre-Damara rocks of central South West Africa marble bands are frequently developed, while extensive deposits of partly recrystallised limestone occur in the Nama Group. The main occurrences of Nama limestone are found in the Zaris Mountains to the west of Maltahöhe, in the Naukluft Mountains southwest of Rehoboth, and in the Huib Plateau and Huns Mountains of the Lüderitz District. Most of the Territory's marble deposits, however, occur in the Swakop Group. The most important occurrences of this age are found in the vicinity of Swakopmund and Karibib, and to the south of Windhoek.

Many of the known deposits are situated far from the main roads, railways or harbours, and high transport costs would render their development unprofitable at this stage. Therefore this report deals mainly with those occurrences which are situated near the main traffic arteries.

B. DEFINITION OF TERMS

1. Dimension Stone

The term refers to naturally occurring rock material cut, shaped, or selected for use in blocks, slabs, sheets or other construction units of specified shapes or sizes, and used for external or interior parts of buildings, foundations, curbing, paving, flagging, bridges or for other architectural or engineering or monumental purposes. The term is also applied to quarry blocks from which pieces of fixed dimensions may be cut (Department of Planning, 1971, p. 122).

2. Marble

"In its geological sense the term is applied to rocks comprising crystallised grains of calcite and/or dolomite. Marble has essentially the composition of limestone or dolomite, the chief difference being that the particles of calcium or magnesium carbonates in limestone usually are granular and non-crystalline. Most marbles are metamorphic rocks resulting from the recrystallisation of limestone.

"Commercially, the word has a wider use. As the ability to take a polish is the chief commercial asset of marble, all calcareous rocks that can be polished are classed as marbles. Furthermore, serpentine rocks that are attractive in colour and pattern and can be polished are classed as marbles, although they may contain little calcium or magnesium carbonates" (Bowles, 1958, p. 1).

Only marble in the geological sense of the term will be considered in this report.

C. INVESTIGATION AND EVALUATION OF MARBLE DEPOSITS

1. Physical and Mineralogical Properties

For an evaluation of the economic potential of ornamental or buildingstone deposits, properties like colour, pattern, texture, hardness, weathering and jointing should be considered in the first instance.

(a) Colour and Pattern

The attractiveness of a marble is determined primarily by its colour and pattern. The colour depends upon its constituents; a rock consisting of pure calcite and/or dolomite is white, while other colours are due to admixture of foreign substances. Distributed uniformly, such impurities give uniform coloration to the marble; appearing in bands or streaks they impart clouded or banded patterns to the rock. Banding can usually be regarded as a sedimentary feature.

The cause of the different colouring is usually easily determined. Black and grey are due to carbonaceous matter, usually present in the form of fine scales of graphite; reddish colours are attributed to the presence of manganese oxides or to hematite, and yellow and yellowish-brown are caused by small grains of limonite. A green colour (verde antique marbles) is due to the weathering of olivine to serpentine.

Beautiful patterns are sometimes found where marbles have been intensely folded or brecciated.

The colour and pattern of the rock to a certain degree determine the purpose for which it will be used. Pure white marble (statuary marble) is preferred for sculpture, whereas brownish types are especially suitable for interior decoration because of their compatibility with the colour of wood. Grey to black, flamed or streaked varieties appear to be in demand for exterior decoration, and mainly white, plain grey and black are used by the tombstone industry.

(b) Composition

Two different types of marble can be distinguished; “calcite marble” which may consist of 95 to almost 100 per cent calcium carbonate ($CaCO_3$), and “dolomite marble” which may contain, if impurities are disregarded, up to 54 per cent $CaCO_3$ and 46 per cent magnesium carbonate ($MgCO_3$); most marbles have compositions varying between these two extremes.

Varying percentages of impurities are present in virtually all types of marble; the most common are silica, either as free SiO_2 (e.g. quartz) or combined in silicates such as tremolite, actinolite, diopside, wollastonite, forsterite, amphibole, mica and chlorite; iron oxides, e.g. hematite or limonite; manganese oxides; iron sulphides (pyrite, marcasite); and graphite. The presence of such impurities usually detracts from the market value in that they may weather faster or slower than the carbonate matter; they may be scattered throughout the mass in dark bands and patches (e.g. mica, chlorite) or they may decompose and cause undesirable discoloration (e.g. pyrite, marcasite).

On the other hand, impurities such as manganese and iron oxides may cause beautiful banding and striking patterns which will increase the value of the rock. A certain content of silica, if scattered throughout the mass, increases the hardness and although the cost of cutting and polishing a hard marble may be high, hardness is a desirable property if the material is to be exposed to abrasion.

(c) Texture

The texture of marble depends on the size, shape and arrangement of the constituent crystals. The grain size is/commonly described as fine, medium or coarse. To place these terms upon an absolute basis, Folk’s (1959) grain size scale for authigenic carbonate rocks was adopted for field use:

Very fine .... less than 0,016 mm
Fine.. 0,016-0,062 mm
Medium .... 0,062-0,25 mm

Coarse...0,25-1,00 mm
Very coarse ....greater than 1,00 mm

It should be mentioned that most of the fine-grained marbles are more durable than coarse-grained ones; they also take a' better polish and are better for intricate cutting or carving.

In certain dolomitic marbles the grains of dolomite may differ largely in size and shape from those of calcite. A noticeable variation in the grain size detracts from the quality as different textures and grain sizes decompose at different rates. A heterogeneous marble will tend to weather and decay in an uneven manner, thus producing a pitted and uneven surface.

There are also remarkable differences between calcite and dolomite in the shape of grains. In a pure calcite marble the grains often show a certain amount of interlocking, whereas in dolomitic marbles they are of simpler shape, and are only occasionally interlocked. As the interlocking of grains has a definite relation to crushing strength, porosity and workability, a high degree of interlocking is a desirable property. The presence of dolomite, which decreases the amount of interlocking and disturbs the uniformity of grain, will therefore only be partially compatible with a high-grade marble.

The calcite and/or dolomite crystals that build up a marble each has a definite cleavage direction. When the crystals, and accordingly also the cleavage planes, are orientated about equally in every direction (statistical arrangement) they compensate each other, and no bad influence on the crushing strength of the stone results. In some marbles, as a result of tectonism, the grains are elongated in more or less one direction so that their cleavage planes are subparallel. This produces in the rock a direction of easiest splitting called "rift" or "grain".

(d) Geological Structure

A good knowledge of the geology of the site is necessary for intelligent and economic quarry development. Through a careful study of outcrops, sufficient knowledge of the main structural features may be obtained to determine the stratigraphic position, thickness, and attitude of the marble beds. Furthermore, the investigator should obtain a good knowledge of the type and extent of jointing. Joints usually occur in regular systems; the occurrence of two sets, more or less at right angles, is very common, but a third and fourth set may also be present. An important point to consider is their spacing. It may be rather variable, as joints tend to occur in groups of closely spaced fractures, separated by masses containing only a few joints. In some deposits joints may be 5 to 10 m apart, but in others the distance is only a few centimetres, in which case profitable quarrying is impossible.

Although jointing is characteristically a surface phenomenon which diminishes with increase in depth, the direction and spacing of joints, as observed at the surface, may both persist with remarkable uniformity to depths of 30 m or more. Consequently joints usually do not fully disappear within the limited depth of a quarry. Only certain fractures, locally known as "hair-lines", normally disappear within depths of 15 to 30 m. These "hair-lines" are regarded as resulting from the daily expansion and contraction of the rocks due to variation in surface temperatures.

Jointing is not always to be regarded as a disadvantage. Near-horizontal and vertical joints may facilitate easy quarrying, provided that they are spaced at reasonable distances and that they have a rectangular pattern.

(e) Weathering

The rate of weathering of a marble depends upon its physical properties and on climatic conditions. Weathering causes a general loosening of the grain interlocking so that the marble becomes crumbly or sugary. At the same time joints will be widened, and previously obscure joints will become open and obvious. Open joints, in turn, promote decomposition in depth. It is not uncommon that circulating water produces solution cavities which later may become filled with soil.

2. Necessity of Core Drilling

Although surface observations, especially with regard to geological structures and joints are of great value, these should be supplemented by core drilling. Because of surface weathering the general appearance and intensity of jointing in the upper part of a deposit may differ considerably from that in the deeper parts. Furthermore the nature and quality of the rock, the thickness of the weathered zone, and the extent of reserves can be determined more accurately by means of core drilling. The cores obtained should be polished on one side in order to facilitate the determination of colour and uniformity of the rock.

The position and arrangement of test boreholes will be determined by the nature of the rock. In flat-lying beds of uniform thickness only a few holes spaced at intervals of 50, 100 or 300 m are necessary; in folded strata or in rocks with varying composition the holes should be spaced more closely. To test the variation in quality, parallel lines of holes should be laid out across the strike, and to determine the nature of jointing at depth, inclined boreholes should be drilled.

II. MARBLE DEPOSITS IN THE KARIBIB DISTRICT

A. INTRODUCTORY REMARKS AND HISTORY

Marble deposits are found on an enormous scale in the vicinity of Karibib and between Karibib and Swakopmund-Walvis Bay. Stratigraphically they belong to the Swakop Group.

Many of these marble occurrences were already known at the beginning of the century. Authors like Gürich (1910), Hagen (1910) and Wagner (1916) mentioned several outcrops of which the following are shown in fig. 1:

White Mountain	:	On the farms Abbabis 70, Etusis 75, Neikhoes 74, Habis 71; white marble.
Hedwigshügel	:	On Habis 71, a few hundred metres west of the old Government railway station; ivory-white marble, but spoilt by yellow spots.
Otjipipopu Mountain	:	On Habis 71, northwest of the old railway station; white marble.
Andreas Mountain	:	On Habis 71, east of the old Habis Station; white marble.
Navachab 58	:	Southeast of Karibib; white marble.
Dernburg Range	:	To the west and northeast of Karibib, extending from Usakos to Okawayo; “fancy” marbles (red white-veined, yellowish-pink, grey, grey banded) .

Mathildenberg	:	Part of the continuation of the Dernburg Range to the northeast of Karibib; "fancy" marbles.
Capra Hill	:	A few kilometres northwest of Karibib Station; white and bluish-grey banded marble.

Marbles of various colours, textures and patterns are therefore present in the area and, although not all material is sufficiently pure and homogeneous for statuary work and much of it is quite valueless due to the presence of tremolite and other silicates, large supplies of marble which might be suitable for architectural and decorative purposes are available.

The vast extent of the deposits and the strikingly handsome appearance of many of the marbles soon attracted the attention of German explorers. In order to work the deposits in the vicinity of Karibib, the Koloniale Marmorsyndikat was floated, but it was put in liquidation in 1912. The properties and rights were then handed over to the Afrika-Marmor-Kolonialgesellschaft which opened up several quarries, the most important ones being those in the Dernburg Range and on Navachab 58. The initial target was an annual production rate of 9 000 m^3 (1 m^3 = 2,7 tons).

Production figures for the pre-war years are stated as follows (Wagner, 1916):

1910 .... 2,9 tons
1911 .... 14,5 tons
1912 .... 249,1 tons
1913 .... 336,1 tons

Between one hundred and two hundred tons were actually shipped to Germany. Judging from the present-day size of the quarries, it would appear that much more marble was removed from them than the above figures would indicate.

After World War I the deposits were again worked intermittently by various companies, but large-scale production was never attempted. No core drilling was carried out and blocks were cut only from shallow quarries. Close jointing at such shallow depths caused the blocks to fall apart during transportation and as a result the marble was regarded as of inferior quality.

At present the marble is used by Marmorwerke Karibib for the manufacture of tombstones, table-tops, wall ornaments and small objects like ashtrays. The stone is obtained either from abandoned quarries or from small-scale quarrying using compressed air drills and wedges.

Another company, Karibib Marble Crush, produces marble fragments of various sizes for the manufacture of terrazzo (used for wall-cladding and flooring). The fines which result from the crushing are sold for roughcasting.

Marble crush from the Skolnic Quarry, 2 km north of Karibib has been used in the construction of the tarred road between Omaruru and Karibib. In the vicinity of this quarry another area is held under concession by a company that is considering the possibility of exploiting the marble for cement manufacture.

B. PRESENT INVESTIGATION

Geological maps by Frommurze, Gevers and Rossouw (1942) and by Smith (1965) were available when the present investigation started.

The area under consideration extends from Usakos to about 10 km east of Karibib (fig. 1). An area of about 450 km^2 was mapped by the first author during 1967 to a scale of 1:12 000. The final maps were reduced photographically to a scale of approximately 1:25 000 (figs. 3 to 5 and folds. 1 and 2). Most existing marble quarries were mapped by plane-table to a scale of 1:1 000 (figs. 6 to 8 and folds. 3 and 4). The weathering and jointing of the marble exposed in these quarries received particular attention.

In addition, l4 diamond core holes which ranged between 7 and 22 m in depth were drilled during 1973 to get an indication of the subsurface nature of some of the most promising marbles. Borehole localities are shown on the maps. Samples of the core were submitted to the National Building Research Institute for investigation; the results will be discussed in a later section.

C. GENERAL DESCRIPTION OF THE MARBLE DEPOSITS

1. Morphology

The country around Karibib is to a large extent characterised by an inselberg topography. Many of the residual hills and mountains are built by marble which is more resistant to weathering than the surrounding schist.

2. Geology

The Karibib marbles occur in the Swakop Group which, in this area, can be subdivided as follows:

Swakop Group	Khomas Subgroup	Mica-quartz schist
		Dolomitic marble (Karibib Formation)
		Diamictite (Chuos Formation)
	Hakos Subgroup	Dolomitic marble

The stratigraphic position of the marbles is shown in fig. 2. They belong to the Karibib Formation of the Swakop Group. In an area of normal stratigraphic development this formation would be underlain by the Chuos diamictite and overlain by schist of the Khomas Subgroup. In the Karibib area, however, the Karibib Formation widely transgresses amphibole schist of the Nosib Group; diamictite of the Chuos Formation was found only on Mon Repos (portion of Navachab 58) and on Kranzberg 59 (Smith, 1965, p. 22).

The Karibib Formation consists chiefly of a thick succession of dolomitic marble with very subordinate intercalations of biotite-quartz schist. The development of this formation varies considerably from place to place. It is therefore very difficult to establish a complete and correct stratigraphic section for this unit. Furthermore, tectonic deformation of the rocks resulted in considerable changes in the original thicknesses of layers. As an incompetent rock, marble most readily yields to folding stresses, and swelling in the crestal portions of the folds combined with an attenuation of the flanks frequently occurs. The computation of the thicknesses proved to be particularly difficult in areas of isoclinal folding where tectonic duplication or multiplication of layers took place. To eliminate some of these possible Sources of error the following profile of the Karibib Formation was measured in a mildly deformed area on Kranzberg Südwest 114:

Mica-quartz schist	
Dark-grey banded marble	100 m
White marble and reddish-brown marble	25 m
Grey banded marble with layers of grey flamed marble......................	225 m
Brownish-grey marble	150 m
Amphibole schist (Nosib Group)	

The overall thickness of the marble here amounts to some 500 m; 35 km farther east, on Okatjimukuju 55, the marble sequence is only 250 m thick and displays the following varieties:

Mica-quartz schist	
Grey and dark-grey banded marble...	20m
White marble..	150 m
Amphibolitic intercalation	5 m
Grey banded, grey and white marble with layers of grey flamed marble..	75 m
Amphibole schist (Nosib Group)	

While the overall thickness has shrunk to about half of that observed on Kranzberg Südwest 114, an even greater variation can be observed in the thicknesses of individual members of the sequence. Figure 2, which is a diagrammatic section across the Usakos-Karibib area, depicts this lateral variation in thickness and appearance of the different marbles. It can readily be seen that reddish marble increases at the expense of the white variety up to Dernburg Hill, where the former has its maximum development. About 20 km to the east of Dernburg Hill a thick sequence of white marble, including a few thin layers of a reddish-brown variety, is again developed. Unfortunately the white marble of that locality has a very coarse grain and is rich in silicate minerals.

From figure 2 it can also be seen that the banded varieties in the upper and lower portions of the marble sequence attenuate in an easterly direction; on Okatjimukuju 55 the banded marbles are preserved as lenses and thin bands only.

3. Tectonics

On the geological map (fig. 1) the trend of the marble ridges can easily be recognised. The northern or Dernburg Range extends from Usakos in a northeasterly direction to Okawayo 46 - a distance of some 35 km. Forming a wide arc, it then turns southwards and approaches the Okahandja-Karibib road. To the south of this road the range turns to an eastwest direction up to Mon Repos (portion of Navachab 58) where it swings to the north and finally meets the Dernburg Range on Navachab 54. The range represents the outer flank of an extensive anticlinal structure, in the centre of which lies the town of Karibib.

An anticlinal structure of similar appearance covers portions of Navachab 54, Kranzberg South 113, Kranzberg Südwest 114, Narubis 67 and Klein Aukas 66.

The structure may seem quite simple when viewed as a whole, but it is very complicated when investigated in detail. The anticline consists of several minor folds, the width and order of which vary considerably, and must therefore be regarded as an anticlinorium.

The easily deformed limestone along the outer flanks of the anticlinorium was much more affected by the tectonic stresses than the rigid masses of Nosib quartzite and amphibolite in the central part. Isoclinal and irregular fold structures are characteristic of these marbles; a flattening of 70 to 80 per cent is not uncommon.

The wide open folds with widths ranging between 100 and 1 000 m must be considered as folds of the second order because they divide the limbs of the large anticlinorium into several smaller anticlines and synclines. These structures are affected by folds of the third order (10 to 100 m range). A fold of the third order within which a further plication can be recognised is shown in plate I. Folds of the fourth order (1 to 20 cm range) are usually found in the cores of the larger structures (pl. II). Beautiful examples of such folds can be observed within the banded marble varieties, e.g. “Zebra” marble of Capra Hill and “Kudu” and “Herero” marble of Dernburg Hill. Locally they can be considered as parasitic folds (pl. III) and sometimes they appear as drag folds (pl. IV).

The fold axes (b-axes) have a common direction which is about northeast, but at many places a considerable deviation from this was observed. The axial plunge may vary from horizontal to 600. Good examples are found at Dernburg Hill.

The impression is gained that after a first phase of folding to which the general northeasterly structural trend of the area may be ascribed, a second compressive phase occurred which brought about northwesterly striking structures. The variation in the strike of the b-axes, which locally may even strike at right angles to each other, can also be explained as follows: during the formation of similar folds, which prevail in the area under discussion, the material of individual beds was redistributed and this led to a swelling of the crestal portions of a fold while at the same time the flanks were attenuated. The thickening of the crestal portions was, however, restricted to a “critical amount of shortening”. When further compression occurred, the material then brought into the inner portions of a structure did not find room and was forced to migrate in a longitudinal direction, thus bringing about a stretching of the fold. By this process, which involves only one phase of folding, the existing fold axes were contorted.

Another phenomenon which is caused by intense deformation of the rock is jointing. It is genetically related to the folding and displays a more or less regular arrangement. Most frequent of all and easiest to recognise are the ac-joints (tension joints which cut the folding at right angles to the fold-axes). They were observed almost everywhere, being spaced at distances ranging from centimetres to metres.

The other joints present a less clear picture, but once their distribution is analysed statistically, two types of joints will be recognised. One is orientated parallel to the fold axis and is inclined towards the axial plane (bc-joints, strike joints or longitudinal joints). They are usually the result of tensile stresses. The other type cuts across the direction of the fold axis at an angle of about 45°. They are called diagonal or shear joints and are nearly vertically disposed. Diagonal joints generally occur in conjugate sets which are arranged more or less symmetrically with relation to the fold axis.

Joints with an almost horizontal attitude were observed in the walls of several quarries (pls. V, VI and VII). It is not quite clear whether they are due to tectonic disturbance or to erosion and unloading.

Occasionally all the different types of joints are found to occur at the same locality; the rock is then completely fractured and useless for the dimension stone industry. Generally, however, only one set of joints is well developed, while the others are subordinate or absent.

Faults with displacements ranging from a few millimetres to hundreds of metres were observed at several localities. Those with displacements between a few millimetres and a few centimetres may locally be quite frequent; they are apparently genetically related to the diagonal joints caused by shearing. Large faults with displacements of up to 200 m are clearly visible on Okawayo 46 and Mon Repos, but they are not a typical feature of the area.

4. Weathering

As far as the Karibib marble-is concerned, solution is probably the most important single agent of weathering and traces of this process are almost ubiquitous; generally the weathered surface of the rock is rough, sharp edged and grooved. Joints are generally widened to fissures, a phenomenon that is especially pronounced near the crests of hills where weathering can also attack from the sides. This type of weathering can reach appreciable depths; in the Karibib "Town Quarry", for instance, solution fissures are more than 15 m deep (pl. V).

Locally, caves have formed in the rock and they are generally filled with marble debris, calcareous mud, or terra rossa-like soil (pl. VI). At some places they are quite large and may penetrate deep into the rock. Series' of cavities may exist without any indication on the surface. It is suspected that the white marble on Navachab 58 ("Navachab White"), amongst others, may be cut by such a system of caves.

The coarse marble breccias on Navachab 58, Karibib 54 ("Damara" marble and Okawayo 46 are regarded as the fillings of large collapsed solution holes or caves.

It seems as if the solution caves formed preferably near the contact between two different types of marble. Examples are to be seen at the contact between the white marble and the dark-grey banded type on Navachab 58, in the "Kudu" marble near the "Rote Brekzie" (Dernburg Hill), and in the "Damara" marble near the grey banded variety.

When a marble contains siliceous impurities, the softer calcareous material is removed faster, leaving the silica-rich portions as distinct ridges on the surface of the marble. Examples are to be seen on Mon Repos (portion of Navachab 58).

Daily variations in temperature can be considerable in the Karibib area. This causes uneven expansion and contraction of the rock which results in the gradual destruction of its outer surface (pl. VII).

In the Karibib area erosion of the higher ground (i.e. removal of decayed rock material) has generally kept up well with the weathering processes so that large areas of bare marble, showing few signs of alteration, are exposed. This was one of the features that attracted the earliest exploiters of the Karibib marble. In localities with only moderate jointing, sound marble blocks could be recovered practically without removing any overburden (see for example pl. VIII).

D. VARIETIES OF MARBLE

The following varieties are prominent enough to be shown separately on the maps (folds. 1 and 2; figs. 3 to 5):

Grey banded
Dark-grey banded

Brownish-grey banded Grey
Light-grey
White and off-white
Reddish and yellowish Green
Flamed
Marble breccias

In many cases different varieties were found to pass laterally into one another. Persistence of colour and pattern can therefore not be guaranteed over large distances, a fact which causes a certain inaccuracy in the representation.

In the following account of the marbles, colours and patterns will be described as far as possible. Quality will be discussed and potential quarry sites indicated. In most cases the reserves can be estimated roughly with the aid of the geological maps. Representative localities are indicated by reference numbers on the maps.

1. Banded Marbles

(a) Dark-grey Banded Marble

A dark-grey, finely banded and generally schistose marble with occasional nests and layers of tremolite is widely distributed along the northern margin of the Dernburg Range between Usakos and Dernburg Hill, where it represents the upper part of the marble succession (fold. 1 and figs. 2 and 3). Small occurrences were also noted on Okatjimukuju 55, Navachab 58, and Man Repos (fold. 1 and figs. 4 and 5). The banding, which is a sedimentary feature, is not equally well developed everywhere. The marble is not sui table for exploitation as dimension stone.

(b) Grey Banded Marbles

This is the variety with the widest distribution in the area. “Grey banded”, however, is a very general term which covers a large variety of marbles. Although grey is the prevailing colour, it displays all shades from almost black to white. They are all banded but vary in appearance from place to place; the banding may be straight or intensely folded. Layers of about the same thickness but with a varying degree of greyness can alternate, but it has also been observed that dark layers a few millimetres thick appear between lighter ones some centimetres thick, or fine light-coloured bands appear within a black marble. The individual layers may be sharply delineated (normal), or pass into each other along indistinct boundaries, as for example near Usakos and Okawayo 46. The banding may be broad (20-100 cm) or fine (2-10 mm). At some, localities individual bands swell to layers 10 to 15 m thick which stand out as white or grey ledges within the generally banded deposit. Such lenses or layers frequently represent deposits of high-grade marble that would be suitable for extraction provided the reserves are large. Lenses or layers of white marble are found at localities 33 and 37 (folds. 1 and 2), while lenses of a grey variety occur at localities 2, 32 and 33 (fold. 1) and at several other places.

It is impossible to show these variations separately on the maps since they rapidly change in appearance, both laterally and vertically. An impression of the different varieties of grey banded marble may be gained from plates III, IV, VII, VIII and IX.

A deficiency common to most banded marbles is the tendency to split along the boundaries of the banding, a property which may become apparent only upon prolonged exposure. This platiness, which coincides with the bedding of the rock and which may occasionally be so pronounced as to resemble a schistosity, is particularly well developed in. the parallelstriped types. When they are intensely plicated, such marbles may give a (false) impression of much greater massiveness (e.g. "Herero" marble, loc. 17, ford. 1; pl. IV).

Banded marble may occasionally lose its banding. This is to be seen in areas where intense recrystallisation took place, as for instance on Okawayo 46. With advancing recrystallisation the banding generally becomes indistinct and eventually vanishes completely to give way to a grey, slightly speckled marble; finally a white graphitic variety may be formed. The wide distribution of white and/grey marble in the Okawayo 46 - Okatjimukuju 55 area may be due to such a process.

Large masses of banded marbles are in some places rendered worthless by impurities. Locally, thin (1-3 cm) intercalations of chert may occur which enhance the flaggyness of the rock (loc. 6, fold. 1). Pyrite is found in many places concentrated in dark layers. As this mineral weathers rather easily, it is an undesirable accessory (locs. 9 and 37, folds. 1 and 2). Silicates such as tremolite or actinolite are quite rare in the banded marbles, although nests of these minerals are occasionally encountered.

The texture of the banded marble varies between fine and coarse grained (Folk's scale, 1959), although by far the majority can be classed as medium grained. The grain size of an individual band is usually quite uniform but in places there is a tendency for lighter bands to be slightly more coarsely crystalline than darker bands of the same sample. As a general rule the banded marbles around Karibib become coarser grained towards the east.

Banded marble was quarried at Capra Hill and Dernburg Hill before World War I and marketed under the names of "Zebra", "Herero" and "Kudu". These marble occurrences will be discussed comprehensively in a later section.

A few hundred metres south of the quarries on Dernburg Hill another site was cleared but actual exploitation never got under way. The marble here consists of bands of more or less equal thickness (approx. 10 mm) but with varying degrees of greyness. The bands can be straight but are more often folded (loc. 11, fold. 1).

Another attempt to start a quarry before World War I was made in "Zebra" marble immediately west of Capra Hill. A shot drill was used to make several large-diameter holes in a stream-bed to facilitate cutting of the marble by wire saws. The rock here is medium to coarse grained (0,125-0,5 mm), attractively patterned and free of excessive jointing (pl. VIII). Large reserves are probably available and sound blocks may be recovered close to the surface, but it has been observed that the cores that have been exposed for over 60 years now show a tendency to split along certain dark pyrite-bearing bands (loc. 29, fold. 1).

In the Skolnic Quarry 2 km north of Karibib grey banded marble is well exposed (loc. 36, fold. 2). The bands are mostly straight but occasionally they are also folded. Individual layers may be white or various shades of grey and vary considerably in thickness. The grain size varies from about 0,125 to 0,5 mm, the darker bands usually being finer. Vertical (ac), steeply inclined (diagonal) and near-horizontal joints are developed with spacing which varies from 0,5 to 2 m. Rock weathering generally does not extend deeper than 1 to 3 m, although one or two solution holes are exposed near the floor of the quarry which is almost 30 m below the original surface. The banded marble of this locality is not regarded suitable as a dimension stone because it is not particularly attractive and some of the darker layers are very pyritic - particularly in the northernmost part of the quarry - with a tendency to split parallel to the banding.

The marble which is mined near Usakos as a source of lime is also of the grey banded type. The rock is coarse grained and light-grey layers 1 to 3 cm thick alternate with dark-grey, brown or greenish ones having thicknesses from 2 to 10 mm. The banding is straight and the rock tends to be flaggy (loc. 1, fig. 3).

(c) Brownish-grey Banded Marble

A dirty brownish-grey banded marble occurs some 4 km southeast of Usakos. It forms the lowest portion of the marble succession and can be traced over a distance of about 12 km. It is not sui table for exploitation as a dimension stone.

Another very small occurrence is situated some 5 km to the west of Karibib. The marble is medium grained with narrow bands; brownish-grey layers about 10 cm thick alternate with feebly banded portions having a pinkish hue. This marble contains pyrite and takes a good polish (loc. 25, fold. 1).

2. Unicoloured Marbles

(a) White and Off-white Marbles

White and off-white marbles are extensively developed in the upper portion of the marble succession, especially east and south of Karibib. Unfortunately the large reserves available to the east of this town, e.g. on Okawayo 46 and Okatjimukuju 55, are practically worthless for the dimension stone industry due to the fact that they are coarse grained, rather brittle, and largely contaminated by silicates.

In general, the lighter coloured marbles appear to have been more susceptible to silicate impurities than the darker or banded types. The weakening of grain interlocking on exposure is also more noticeable in the pure white variety. Although solution cavities are frequently developed, joints are usually spaced at fair distances.

Fine to medium grained white marbles are found on Navachab 58 and at Dernburg Hill. Elsewhere grain sizes vary from medium to coarse.

White marble has been quarried at three localities within the area, viz. Navachab 58 (loc. 8, fold. 1), Karibib "Town Quarry" (loc. 44, fig. 4), and Mon Repos (loc. 34, fig. 5). These occurrences will be discussed in a later section.

At Dernburg Hill there are two noteworthy occurrences of white dolomitic marble. The first extends as a broad band about 4 km long and 50 to 250 m wide along the southern flank of this hill. The colour and texture change rapidly along both strike and dip; the colour varies between pure white and very pale greyish or pinkish-white while grain sizes are between very fine and medium. Jointing is generally intense and irregular on the surface and calc-silicates are rather common. A dense very fine grained marble with a conchoidal fracture is developed locally. Although this occurrence may not be suitable for large-scale exploitation, a few sound blocks for special (e.g. statuary) purposes could be obtained from the surface by selective small-scale quarrying (loc. 24, fold. 1).

The second area of interest is along the northern slopes of Dernburg Hill, a few hundred metres south of the Karibib-Usakos main road. A dolomitic marble which, on closer inspection, proves to be a sedimentary breccia consisting of white fragments enclosed in ,an off-white matrix, forms bands 20 to 40 m wide which are exposed intermittently over a distance of almost 1 km. The angular clasts are fine to medium grained and vary in diameter from a few millimetres to several centimeters. The matrix is coarse to very coarse grained. The marble consists of 30 to 70 per cent calcite, the higher percentage being found in the matrix. Undesirable accessories like calc-silicates and pyrite are rare. This marble is virtually unaffected by weathering and jointing and sound blocks could be recovered from the surface with a minimum of waste.

One borehole 21 m deep was drilled here at a particularly favourable site for a potential quarry and it was found, against expectations, that the quality of the deposit deteriorated from about 12 m downwards due to subsurface jointing and pyrite mineralisation. Nevertheless, it is conservatively estimated that the available reserves of .sound marble at this particular spot amount to some 100 000 m^3 (loc. 23, fold. 1).

A marble similar to the one described above, although on a smaller scale, occurs at Capra Hill. The pattern of the rock can be seen very well on weathered surfaces (loc. 31, fold. 1; pl. XI).

A few kilometres to the northeast a layer of coarsely crystalline compact cream-coloured marble 15 to 20 m thick has developed within a grey banded variety. The colour is accentuated by grey and pink streaks. The rock can be polished without difficulty. Reserves are small as the layer attenuates towards the northeast to a thickness of some 2 m (loc. 39, fold. 2).

(b) Grey and Light-grey Marbles

Grey marbles, displaying all hues from nearly white to almost black and sometimes also bluish to brownish tints, occur in the area. Only a few of the numerous outcrops will be described.

Light-grey, almost white, fine grained marble is found some 2 km northeast of the homestead on Navachab 58; it rests upon a grey banded variety and shows all gradations from pure white to silver grey (loc. 21, fold. 1).

A similar silver-grey type with darker streaks occurs a few hundred metres west of the homestead on Navachab 58. It is a fine grained rock which locally displays pink to bluish tints and becomes darker towards the southeast. It is feebly banded in places and is locally rich in silicates (loc. 7, fold. 1).

To the west of Capra Hill a lens of medium to coarse grained bluishgrey marble approximately 20 m thick crops out within banded marbles. The rock is massive and nearly free from impurities. As reserves are small it can be quarried only on a limited scale (loc. 27, fold. 1).

A fine to medium grained marble, dove grey and medium grey with a few irregular white streaks, occurs immediately north of the Skolnic Quarry. It has been exploited on a small scale by Marmor-werke Karibib. The rock is dense and takes a good polish; slabs of this marble have been used for internal decoration of the State Hospital in Windhoek (pl. XIII). Unfortunately reserves are small (loc. 38, fold. 2).

(c) Reddish and Yellowish Marbles

Reddish and yellowish marble occur mainly at Dernburg Hill and at Mathildenberg northeast of Karibib. As a rule the deposits at the lastmentioned locality are coarser grained and more brittle than those of Dernburg Hill.

At Dernburg Hill exploitation of a pink variety (trade name “Esserando”) started during German colonial times. Discussion of the “Esserando” marble will be deferred to a later section.

Fine to medium grained beige marble attaining a thickness of some 30 m, but including bands of a grey banded variety a few metres thick, is present on Navachab 58. A few thin layers particularly rich in iron oxide were noted in the otherwise homogeneous rock. The whole rock has been intensely crumpled and deformed. A platy splitting was observed locally (loc. 3, fold. 1).

A coarse grained cream-coloured marble which locally passes into a brownish or reddish-yellow variety occurs on Okawayo 46. It extends for several hundreds of metres along the strike and is about 30 m thick. Unfortunately the rock is brittle, contains silicate impurities and is locally intensely jointed (loc. 43, fold. 2).

A reddish to yellowish-brown medium grained dolomite marble occurs 4 km north-northeast of Karibib on the Omaruru road. It is rich in silicates locally and is cut by darker brown and reddish-brown lines which are probably fine cracks filled by iron compounds (loc. 4l, fold. 2).

In a southwesterly direction from this locality the marble becomes coarser grained and possesses an even salmon colour; an excellent example is found some 600 m from locality 4l and next to the Omaruru road. The rock is not completely free from silicates and the colour changes to yellowish brown locally. The calcite content varies between 10 and 20 per cent (loc. 40, fold. 2). One borehole almost 17 m deep was drilled to test this marble. It was found that it would be unsuitable for exploitation as dimension stone mainly because of poor interlocking of the grains. Furthermore, frequent hair-line cracks which may open upon quarrying and small solution holes (some as deep down as 15 m) detract from the value of this deposit.

Near the northwestern extremity of Dernburg Hill a mustard-yellow marble is developed in the same horizon as the pink “Esserando”. It can probably be correlated with the highly fractured nature of the rock which locally has permitted weathering of hematite (colouring substance of the “Esserando”) to finely dispersed limonite. This yellow rock occurs over a very small area only and drilling has shown that the yellow coloration becomes very irregular within one or two metres from the surface. Deeper down the yellow is irregularly mixed with various shades of red, grey and white. This could have been a very attractive marble but for the intense fracturing which persists in depth (loc. 16, fold. 1).

(d) Green Marble

In the Karibib area only one small occurrence of green marble was found on Mon Repos (ptn. 3 of Navachab 58). The colour is due to the serpentinisation of olivine (forsterite), an original accessory mineral. Only restricted portions of the occurrence display this colour. In addition to green, yellow, red and brownish colours were noted. The marble is medium to coarse grained. Because of its small extent and the frequent change in colour this occurrence is not suitable for large-scale quarrying (loc. 35, fig. 5).

(e) Black Marble

Pure black marble is comparatively rare and usually occurs as bands or lenses within the dark-grey or grey banded types. It has not been shown separately on the maps.

A high-grade deep-black marble, which is enlivened by a few thin white streaks, has been quarried on a small scale by Marmorwerke Karibib at a hill approximately 1 km north of the Navachab homestead. The rock is medium grained and dense, but unfortunately reserves are too small to warrant large-scale exploitation (loc. 10, fold. L).

In the central western part of Dernburg Hill bands of black marble are more frequently developed in the grey banded type than anywhere else. All these occurrences are of limited extent.

A deep-black dolomite marble occurs in the northern flank of Dernburg Hill. It lies in the core of a third-order syncline within the previously described white marble breccia. The rock, which takes a good polish, is fine to medium grained and very dense. Reserves are small and quarrying could be considered only in conjunction with the underlying white breccia (loc. 23, fold. 1).

3. Marble Breccias

Two types of breccia which differ markedly in their mode of origin and occurrence are found within the area.

(a) Sedimentary Breccias

Layers of flamed marble up to 15 m thick are found-at many localities. They usually protrude like reefs from the surrounding grey banded marbles and can be traced over hundreds of metres. Their strike coincides with that of the surrounding marble.

The flamed marbles are easily recognised as breccias: they consist of oblong, angular, predominantly white marble fragments set in a matrix of mainly grey or dark-grey marble. They range in diameter from a few millimetres to tens of centimetres. The number of fragments within a given volume of rock may vary widely. There are also examples of breccias in which both matrix and fragments have the same colour. One such occurrence at Dernburg Hill (loc. 23, fold. 1) has already been mentioned. These rocks can be recognised mainly because of differential weathering of fragments and matrix. At Dernburg Hill a breccia with a reddish-brown matrix is also present (loc. 14, fold. 1).

Fragments and matrix are usually of the same crystallinity. The rock as a whole, however, may vary from fine to coarse grained. The finer the grain the sharper the outlines of the fragments become (e.g. loc. 4, fold 1), but with an increase in grain size the boundaries become indistinct and the marble becomes indistinctly streaked (e.g. loc. 26, fold. 1).

Since the fragments and the enclosing matrix are recrystallised to the same extent, the breccias are believed to have originated before recrystallisation took place. They should also be older than the folding, since they are aligned parallel to the strike of the surrounding marble. The breccia therefore appears to be of sedimentary origin - probably an intraformational breccia.

The breccias are not persistent along strike and, due to the intricate fold pattern of the area, it is not possible to correlate single layers and to determine exactly how many of them have developed. In the vicinity of Okawayo 46 and farther eastwards breccias do not seem to have developed at all, whereas to the southeast of Usakos and on Navachab 58 they occur along at least two stratigraphic levels.

Being older than the folding, the breccias were subjected to varying degrees of deformation which caused lateral attenuation of the fragments. All elongated fragments show a preferred alignment but this may, to some extent, be of sedimentary origin. At some localities the fragments have such indistinct boundaries that they appear to have been fluid (loc. 20, fold. 1; pl. XII).

At other localities they are flattened to such an extent that the marble appears to be thinly banded. The outlines of the fragments are recognised only when seen in two or three dimensions.

Flamed marble (sedimentary breccia) has been quarried on a small scale at several localities, of which the more important, the “Rote Brekzie” at Dernburg Hill, will be discussed in more detail later.

Another small occurrence at Dernburg Hill was exploited before World War I by dislocating large masses of rock from a high cliff. The marble was then cut into blocks by wire saws. Although this breccia is quite attractive, most of the larger blocks are rendered useless by diagonal fractures, many of which have opened as a result of exposure over a period of 60 years (loc. 12, fold. 1).

More recently a small occurrence of grey flamed marble has been exploited by Marmorwerke Karibib at a locality 1 km west of Capra Hill. Two varieties are present here - one with white fragments embedded in a darkgrey to black matrix, while the groundmass of the other is light grey (trade name “Sander”). In other respects the two marbles are very similar. They are medium grained but very dense and the boundaries of clasts are rather diffuse. Both the black flamed and the light-grey flamed (“Sander”) have been used for cladding on buildings in Windhoek, Walvis Bay and Karibib. Reserves at this locality warrant only small-scale quarrying (loc. 28, fold. 1; pl. X and XIV).

A breccia similar to the black flamed variety described above is also found in the small quarry at locality 10 (pl. XV). Furthermore, two bands of light-grey flamed marble 15 to 5 m wide are well exposed in the Skolnic Quarry 2 km north of Karibib, where it is exploited for crushed stone.

(b) Collapse Breccias

Coarse marble breccias are found at the following places:

Locality 5 (Navachab 58)
Locality 13 (Karibib 54)
Locality 22 (Karibib 54)
Locality 42 (Okawayo 46)

Angular fragments of marble measuring up to 2 m across are included in a matrix consisting of calcite or reddish limestone. The fragments are all derived from marble types which are found in the immediate neighbourhood. The boundaries with neighbouring rocks are discordant and distinct.

Contrary to the sedimentary breccia described above, this type of breccia is younger than the folding, as some of the fragments are folded. It is also younger than the regional metamorphism of the area, since there is a distinct difference between the recrystallised fragments and the limestone forming the matrix. The rock is believed to be a collapse breccia which originated .through foundering in large solution cavities. This explanation is supported by the red colour of the rock, which is due to the presence of iron oxides probably derived from terra rossa originally present in the cavities.

The coarse breccia has been quarried at one locality only (loc. 13, fold. 1) and marketed under the trade name “Damara”. The “Damara” marble will be discussed more fully in a later section.

A small occurrence of bright red-brown breccia with fragments up to 50 cm across is also found at Dernburg Hill. Its matrix and fragments are impregnated by iron oxides. The deposit is poorly situated on top of the hill, is intersected by numerous fractures, and reserves are limited (loc. 22, fold. 1).

The breccia which occurs at the boundary between Navachab 58 and Kranzberg 59 consists of reddish, yellowish, grey and white fragments which vary in diameter from a few centimetres up to one metre. They are embedded in a medium-grained reddish groundmass and the rock is well consolidated. Although reserves are sufficient it will be almost impossible to obtain marketable blocks, at least within the first few metres from the surface, because of the severe jointing (loc. 5, fold. 1).

The coarse marble breccia situated some 6 km northeast of Karibib on Okawayo 46 is more irregularly distributed than was possible to show on the map. It consists of angular white, grey and yellow-brown clasts which average between 20 and 50 mm in diameter, although larger fragments up to one metre are not uncommon. The matrix is white, reddish and yellowish brown, and coarsely crystalline. Coherence of the rock is rather poor and some of the clasts, especially the yellow-brown ones, tend to be crumbly. A borehole 10 m deep indicated that small solution holes are common and that there was no appreciable improvement in the quality of the rock with depth (loc. 42, fold. 2).

4. Miscellaneous

In addition to the main types of marble mentioned in the foregoing pages, other attractive varieties are occasionally developed on a very small scale (reserves can be expressed in tens of cubic metres). Marmorwerke Karibib has exploited some of them for special decorative purposes and for the manufacture of various ornaments. One locality is at the western extremity of Dernburg Hill, where very attractively banded and variegated coloured marbles with trade names “Antilope”, “Leopard” and “Ewinde” have been quarried (loc. 15, fold. 1; pl. X). At another spot about 1 km north of Onguati Siding a few small blocks of beautifully banded aragonite have been recovered (pl. X).

E. THE MORE IMPORTANT DEPOSITS

1. Pink “Esserando” Marble at Dernburg Hill

(a) Location and Previous Work

The deposit (loc. 19, fold. 1 and fold. 3) is situated approximately 10 km west of Karibib on the northern slope of Dernburg Hill and can be reached by following the main road to Usakos. Two quarries were established in the “Esserando” marble during German colonial times. Quarrying was continued during the period 1953-54 by an associate company of Robertsons Stone (Transvaal) (Pty) Ltd. In the main quarry three faces 10, 12, and 35 m long and up to 6 m high were cut by means of a wire saw. Blocks up to 1 m^3 and more were cut, some of which can still be seen in the quarry (pl. XVI). In the second quarry, which lies some 150 m farther southwest, two faces 15 m long and 3 to 5 m high, and a slot 5 m wide and 6 m long were prepared with wire saws.

(b) Geology

The marble occurs in the upper part of the Karibib Formation. The following succession was noted (from top to bottom):

Dark-grey banded marble
Pink marble ("Esserando")
Brown and grey banded marble ("Kudu")

The dark-grey banded variety is exposed to the north of the "Esserando" type at the foot of the hill but it is not suitable for dimension stone quarrying. The "Kudu" marble has also been quarried in the past and will be discussed separately.

The "Esserando" marble forms a massive layer up to 45 m thick. The bedding, which is revealed by layers rich in actinolite, strikes northeast. The strata form the northwestern limb of an overfolded anticline and dip steeply to the southeast (section C-D, fold. 1). In the northeastern portion of the deposit area the marble band is bent into a narrow subsidiary anticline with the axis plunging steeply (60°) to the northeast. In some places its northern limb was subjected to intense folding and the axes of these secondary folds are aligned parallel to the main axis.

The "Esserando" is a pink dolomitic marble with occasional yellow streaks and white veins of coarse calcite. The rock consists of roughly 70 per cent dolomite and the grain size varies between 0,125 and 0,5 mm, the average being about 0,25 mm. The colour is also variable between light pink and a darker reddish-pink, and it is criss-crossed by numerous hairline cracks that are sealed by reddish-brown iron oxides. Apart from small amounts of quartz and mica, the rock is mainly contaminated by needles of actinolite, up to 30 mm long which are generally concentrated in layers which can be as wide as one or two metres.

Under the microscope the carbonate grains are angular and to a large extent idioblastic. The contacts between the individual grains are usually straight or occasionally slightly curved. Interlocking is almost absent. The texture of the white veins is quite different; they consist of coarse calcite crystals with very irregular outlines and showing a rather high degree of interlocking. Nevertheless these "filled" joints constitute zones of weakness because the rock tends to break along the boundaries between the veins and the surrounding marble.

The marble is rather strongly and irregularly jointed. Apart from local irregular cracks caused by recent blasting and the calcite veins mentioned above, three sets of joints striking northeasterly, northwesterly and north-northeasterly are present. Those orientated northeast are parallel to the bedding. The joints striking northwest are ac-fractures, i.e. tension fractures orientated perpendicular to the fold axes. As the latter plunge steeply to the northeast, the ac-joints consequently dip southwestwards at angles between 45 and 60°. The spacing is generally narrow - the distances between individual joints being 30 to 60 cm. The remaining north-northeast-striking joints represent one of two conjugate sets of diagonal joints. They cut across the direction of the fold axes at an angle of about 45° and dip steeply or even vertically. In places the other conjugate set striking roughly east-west, or both sets, may have been developed together. The spacing of these fractures is variable and ranges from centimetres to metres.

One borehole almost 20 m deep was drilled close to the main "Esserando" quarry. The core revealed that the jointing observed on the surface persists in depth, also that below 7 m the colour of the marble changes to variegated pink, reddish brown, yellowish brown, various shades of grey, and white, although pink still predominates.

(c) Exploitation

The "Esserando" marble is undoubtedly one of the more attractive types present in the Karibib area. Its compatible colour renders it particularly suitable for use in combination with wood and also for interior decoration in general. Reserves are extensive, but unfortunately the recovery of large sound blocks will be difficult due to the irregular jointing, and considerable wastage must be expected. Smaller slabs measuring several tens of centimetres in each direction have been used on a small scale to decorate certain buildings in Windhoek (for an example see pl. XXI). Of late the marble directly east of the main "Esserando" quarry has been exploited for the manufacture of marble crush. The explosives used in this process have undoubtedly has a detrimental effect on the rock in the immediate vicinity.

2. Brown and Grey Banded "Kudu" Marble and "Rote Brekzie" at Dernburg Hill

(a) Location and Previous Work

The deposits (loc. 18 and l4, fold. 1 and fold. 3) lie about 1 km south of the Karibib-Usakos main road. They were worked in German colonial times, and during the period 1953-54 by Robertsons Stone (Tvl.) (Pty) Ltd. The quarry was established on the contact between "Kudu" marble and "Rote Brekzie". Its position near the crest of Dernburg Hill cannot be considered favourable, although "Kudu" marble is found only along the crest of the hill.

Three quarry faces each about 10 to 12 m long and 3 to 5 m high, and a slot about 10 m long, 5 m high and 1 m wide, were prepared by means of a wire saw. Blocks of "Kudu" marble, some exceeding 1 m^3, were cut from an area of about 15 by 15 m and moved down the slope on a chute for shipment. Some of these are still lying in the quarry (pl. XVII). A few blocks of "Rote Brekzie" have also been recovered here.

Two other slots were prepared in the "Rote Brekzie"; one is situated some 50 m to the southwest and the other about 170 m east of the main quarry. It is possible that these slots were laid out for prospecting purposes only.

At present (1973) the "Rote Brekzie" is exploited some 300 m southwest of the main quarry for the manufacture of marble crush.

(b) Geology

The "Kudu" marble has a restricted development towards the top of the grey banded marbles of the Karibib Formation. The following succession was noted (from top to bottom):

Pink marble ("Esserando")
Brown and grey banded marble ("Kudu"),
including a layer of sedimentary breccia
("Rote Brekzie")
Grey banded marble.

In the vicinity of the quarry the marble bands strike roughly northeast forming part of the northern limb of a major anticline which is overfolded towards the northwest. Farther northeastwards the whole succession is bent into a subsidiary anticline with an axis plunging northeastwards. Together with this large-scale folding, strong plication of the individual layers also took place. This feature is very well exhibited by the banded "Kudu" marble in the northeastern quarry face (pl. III).

The "Kudu" marble can be followed for about 100 m along strike and attains thicknesses of up to 50 m; the boundary between it and the ordinary grey banded marble is transitional.

It is pale grey to grey with reddish-brown, brownish-grey, dark-grey and white bands (pl. IX). The thickness of the bands, which are either straight or highly puckered, ranges from less than 1 mm to about 10 mm; individual bands thin out to mere threads. The pale-grey to grey groundmass of the "Kudu" marble has an equigranular texture and individual grains are well interlocked. The average grain size lies between 0,125 and 0,25 mm. The brown and dark-grey bands consist of fine grained carbonate and traces of quartz, mica, and iron oxides. The boundaries between these bands and the groundmass are sharp so that the marble tends to split along the banding.

Within the succession of "Kudu" marble the "Rote Brekzie", a sedimentary breccia about 10 m thick, is developed. The "Rote Brekzie" can be followed for several hundred metres along strike. Farther towards the west and east it attenuates and passes into ordinary grey flamed marble. The breccia consists of angular fragments of white and light-grey marble in a reddish-brown matrix (pl. IX). The clasts measure up to 10 cm across and are randomly distributed in the matrix. The latter is fine to medium grained while the fragments are medium grained (average about 0,25 mm). The individual grains are usually well interlocked so that the marble is massive and dense. Small amounts of quartz occur in the rock.

Two main sets of joints striking in northerly and northwesterly directions are visible on the quarry floor (see inset on fold. 3). The set that strikes north can be regarded as diagonal joints which cut across the general direction of the bedding at an angle of about 45°, while the other represents ac-fractures. Both are nearly vertically disposed and the spacing ranges from 50 cm to 2 m. In addition, horizontal fractures have developed in both the "Kudu" marble and the "Rote Brekzie". They are especially abundant in the southwestern quarry face. The horizontal fractures exhibit the somewhat irregular outlines of tension joints (pl. VII). From the surface down to a few metres, a close network of irregular cracks has developed (pl. VII). These are believed to have resulted from daily fluctuations in temperature. Solution channels and cavities partly filled by marble fragments and soil have been observed at several places in the deposit area.

(c) Exploitation

Since the "Kudu" marble tends to split along the banding, recovery of large blocks will result in considerable wastage. Owing to its beautiful pattern, however, it may be marketed for special decorations and thus fetch a high price. As it is quite possible that the rock is more compact at greater depths, the quarry should be deepened. The position of the quarry on the crest of a hill was not a good choice, as weathering can attack the rock from three sides.

"Rote Brekzie", a marble which also possesses a striking colour and pattern, will be suitable for embellishment of buildings. It should, however, be possible' to find a better quarry site farther southwestwards. The "Rote Brekzie" crops out in a long band about 10 to 20 m wide, and quarrying operations could therefore be rather inconvenient. Furthermore, small amounts of quartz in the rock may render cutting and polishing more difficult than usual.

The reserves are estimated to be:

“Kudu” marble - more than 7 500 tons per metre depth.
“Rote Brekzie” - more than 15 000 tons per metre depth.

J. Grey Banded “Herero” Marble at Dernburg Hill

(a) Location and Previous Work

The deposit (loc. 17, fold. 1 and fold. 3) is situated near the foot of Dernburg Hill, about 10 km west of the nearest railhead, Karibib. It was worked between 1910 and 19l4 and probably also during 1953-54 by Robertsons Stone (Tvl.) (Pty) Ltd. Two slots of about 10 and 15 m long, 1,5 m wide and 3 to 5 m high and a quarry face more than 20 m long and 2 to 3 m high were cut by means of a wire saw in strongly folded grey banded marble in the upper regions of a little valley. Marble blocks of 1 m^3 and even more were cut from an area of 8 by 25 m. A number of these blocks are still lying near the quarry.

(b) Geology

The “Herero” marble is developed in the upper portion of the grey banded marble in the vicinity of Dernburg Hill. Locally it is overlain by the “Kudu” variety, into which it passes gradually.

In this area the rocks strike east-west, the dip being vertical or steeply to the north or south. The “Herero” marble is intensely folded with numerous small drag folds (pl. IV). This characteristic feature is best developed in an area a few hundred metres square which immediately surrounds the “Herero” quarry.

The “Herero” marble is a thinly banded highly plicated fine to medium grained rock with an average grain size in the vicinity of 0,125 mm. It consists of a grey groundmass interspersed by dark-grey, white or lightgrey bands (pl. IV). The thickness of individual bands ranges from 0,5 to 10 mm, but usually they are 1 to 2 mm wide. Siliceous impurities are rare in the deposit area; pyrite is more common, particularly in the darker bands. Occasionally thin white streaks of coarsely crystalline calcite are present. Although the strong plication has caused a certain interlocking of the individual layers, the rock still tends to split along the banding, especially along those that are pyrite bearing.

Apart from fractures along bedding planes there are three main sets of joints developed, namely along northerly, easterly and northeasterly directions.

The joints striking north are ac-joints, i.e. tension fractures orientated perpendicular to the fold axes; they are spaced from 0,5 to 2 m apart. The east-west orientated set of joints is developed parallel to the fold axes. They are strike joints, dipping at small angles (15°-30°) either to the north or to the south. Some of them have been widened by solution, as can be seen on the eastern quarry face. The joints striking northeast represent one of the two conjugate sets of diagonal joints which cut across the direction of the fold axes at an angle of about 45°; they usually dip vertically. Strike joints and diagonal joints are not equally developed throughout the deposit area; they are closely spaced at some places, but may be absent at others.

There are also many irregular and rather closely spaced “hair-lines” present in the “Herero” marble. Along many of them small-scale displacement has taken place. They are usually tight, although some of them have opened in blocks that have been lying around in the quarry for more than 60 years. Weathering effects are minimal in the deposit area; only a few joints have been widened to solution channels.

A vertical borehole 22 m deep was drilled some 25 m west of the "Herero" quarry. The core revealed that the jointing as well as the type and intensity of folding observed on the surface remains virtually unchanged within the interval penetrated. Below 12 m the groundmass of the marble becomes partly pinkish. The number of dark-grey bands decreases from 14 m downwards and they are usually grouped in thin zones at 50 cm intervals. Over the last 1,5 m of the core many dark reddish-brown bands up to 1 mm wide are present.

(c) Exploitation

Relatively closely spaced jointing inhibits proper exploitation at the present quarry site. Farther south the jointing seems to be less pronounced, but since the rock is less folded and the bands accordingly less interlocked at that locality, parting of the rock along the banding may be more pronounced. Also, the "Herero" marble owes its attractive pattern to the intense folding.

Reserves of the "Herero" marble amount to several million tons. It has an attractive pattern which may be very suitable for certain large-scale decorative purposes. Unfortunately a considerable amount of waste must be expected if the recovery of large blocks is attempted.

4. "Damara" Marble Breccia at Dernburg Hill

(a) Location and Previous Work

The deposit (loc. 13, fold. 1 and fold. 3) lies near the western extremity of Dernburg Hill. It was worked in German colonial times, and probably during 1953-54 by Robertsons Stone (Tvl.) (Pty) Ltd.

Quarrying took place on the contact between the "Rote Brekzie" and "Damara" marble. Three faces 10, 12 and 25 m long and 3 to 5 m high, and a slot 1 m wide and 8 m long were cut with a wire saw. Blocks exceeding 3 tons in mass were recovered from an area 10 by 25 m, trimmed, and some of them shipped. Others are still lying in the quarry. Some 100 m farther to the southeast a slot 1,5 m wide and about 10 m long was cut by means of a wire saw, probably with the intention of opening another quarry.

(b) Geology

The breccia forms an oblong dome-like outcrop measuring 100 m by 200 m. The boundaries with the neighbouring rocks are discordant and distinct. The fragments generally measure between 10 and 20 cm but may be up to 1 m across. They are randomly distributed in the matrix and have been derived from rocks of the Karibib Formation in the immediate neighbourhood (pl. IX). Fragments of the "Rote Brekzie" are thus found only in the northeastern portion of the outcrop, whereas in the remainder of the "Damara" marble, fragments of grey banded marble prevail. The matrix consists either of medium to coarsely crystalline calcite or of consolidated reddish-brown and grey highly calcareous matter. The fragments are fairly well cemented by the matrix, but the latter tends to become friable on exposure.

There are no regular sets of joints in the "Damara" marble, but many irregular fractures and cracks are developed preferredly in the matrix. Only rarely is a fracture seen to cut across a fragment.

Several solution holes and channels measuring up to 1 m across and partly filled with red soil and small rounded marble blocks were noted. Furthermore, an inclined borehole of just over 8 m showed that vugs ranging from a few millimetres to tens of centimetres in diameter occur at a frequency of slightly more than one per metre core. Many of these vugs are lined with beautiful calcite crystals.

(c) Exploitation

In the existing quarry, recovery of large blocks will cause considerable wastage. Another quarry in which the deeper lying portions of the marble breccia can be quarried could be considered. It should be possible to find a more favourable site at the southern boundary of the deposit. Provided that sufficiently large sound blocks could be obtained, "Damara" marble should be very suitable for large-scale interior decoration. Reserves are estimated at about 30 000 tons per metre depth, of which some 10 per cent will be accounted for by a particularly attractive rock which incorporates clasts of "Rote Brekzie".

5. "Navachab White" and Silvery Grey Marble on Navachab 58

(a) Location and Previous Work

The deposit (loc. 8, fold. 1 and fig. 6) is situated approximately 15 km southwest of Karibib. It can be reached by following the tarred road between Karibib and Usakos for about 10 km and then turning left on to a fairly good farm road running south. During German colonial days a quarry was established in the white marble of this deposit immediately to the west of its contact with a dark-grey banded variety. The quarry faces, 15 and 20 m long and 1 to 2 m high, were cut by means of a wire saw. Blocks exceeding 1 m^3 were cut, trimmed and shipped.

(b) Geology

The following succession was noted in the immediate vicinity (from top to bottom):

Dark-grey banded marble (unsuitable for exploitation)
White marble (siliceous in places)
Silvery grey marble (siliceous in places)

The marble strikes roughly north-northeast and dips steeply to the east-southeast. The silvery grey variety forms the core of a narrow almost isoclinal anticline on both limbs of which white marble occurs (section EF, fold. 1). Highly siliceous, ferruginous intercalations which stand out as prominent ridges from the marble, and which weather to brown gossanlike outcrops, are scattered over the whole area of the deposit. The marble generally becomes more siliceous towards the south and west. It is cu by an eastward-trending dolerite dyke.

The "Navachab White" is a pure white marble which contains 50 to 80 per, cent of dolomite. It is equigranular with an average grain size in the vicinity of 0,25 mm. Interlocking is usually fairly good but often the marble tends to be sugary, especially near joints and solution cavities. The most frequent impurities are calc-silicates which occur in the form of white fibrous crystals up to 2 cm long. The marble is comparatively free from silicates in the vicinity of the quarry; south of the dolerite dyke, however, the amount of impurities increases.

A variety with a silvery grey to light bluish-grey colour occurs farther towards the west. The rock may exhibit this hue throughout or in streaks and patches only. The marble is dense and translucent at the edges. It is slightly finer grained than the "Navachab White", equigranular, and the grains are fairly well interlocked. Impurities in the form of diopside and actinolite increase in amount from east to west.

Two main sets of joints were noted, one directed north-south, the other east-west. A third poorly developed set strikes about northwest. Those striking north-south are developed more or less parallel to the bedding planes, whereas those orientated east-west may be regarded as ac-joints. The joints are spaced between 0,5 and 1 m at the surface but the silvery grey marble seems to be jointed to a lesser degree than the white variety. Irregular horizontal fractures are due to weathering and disappear within a few metres from the surface.

The marble has been affected by fluctuations of temperature to depths not exceeding 2 m. Gradual destruction of the texture of the rock results in a sugary surface, and the upper portions are crossed by irregular cracks. The effects of solution, however, reach deeper and are much more detrimental. Numerous joints are widened to solution channels 10 to 30 cm wide, 30 of which were observed in an area of 100 m^2. Many of them are at least 10 m deep.

Three boreholes (MI, M2 and M3) were drilled close to the quarry (Fig. 6). None of these holes could be drilled deeper than between 7 and 11 m due to numerous solution cavities which resulted in heavy water losses. These cavities are from a few centimetres to 1 m in diameter. They appear to be much less numerous in the silvery grey variety, which was penetrated by borehole M3. The quality of the marble encountered throughout borehole M1 (11 m, vertical) was poor, mainly because of its sugary texture, but a considerable improvement was noted in the lower portion of borehole M2 (7 m, inlined at 350 W) and especially in borehole M3 (7,20 m vertical).

(c) Exploitation

Although the "Navachab White" is an attractive pure white marble, largescale quarrying cannot be recommended because of the many irregularly distributed cavities and, to a certain extent, silicate impurities. The joint pattern should facilitate the recovery of smaller blocks but their ability to stand up to prolonged weathering is questionable.

The silvery grey variety that occurs westwards of the existing quarry seems to offer a more promising proposition. This marble should be suitable, amongst other things, for interior cladding of buildings.

The following are estimates of reserves of marble that are comparatively free from silicates:

White marble	-	more than 10 000 tons per metre depth
Silvery grey marble	-	more than 12 000 tons per metre depth.

6. White Marble of the "Town Quarry", Karibib

(a) Location and Previous Work

The deposit (loc. 44, fig. 4 and fig. 7) is situated approximately 5 km southeast of Karibib and can be reached by following the Karibib-Otjimbingwe road for the first 5 km and thereafter by a 3-km long track running east-northeast. It was worked during the period 1953-54 by Robertsons Stone (Tvl.) (Pty) Ltd. The quarry is situated on the southern slope of a hillock, and its face of about 12 m long and 5 m high was cut by wire saw. Marble blocks were recovered from an area of about 20 by 20 m.

(b) Geology

The marble strikes northwest with a steep dip to the southwest. Since the rock is massive and almost lacks banding, it is difficult to recognise the bedding and to determine the structure of the area. The deposit seems to be situated on the northern limb of a syncline. The marble is pure white, dense, and consists of almost 100 per cent dolomite. It is medium to coarse grained (average grain size 0,5 mm) and equigranular. The individual grains are fairly well interlocked. Silicate impurities are practically absent. In places the white of the rock is enlivened by slightly ferruginous pink streaks lying about 30 to 50 cm apart. The rock tends to become sugary on exposure at the surface and also along joint planes. Four sets of joints are visible on the quarry floor (inset on fig. 7) and strike in northerly, easterly, northeasterly and northwesterly directions.

The joints striking northwest are comparatively rare; they are developed on bedding planes. Fractures orientated in a southwesterly direction can be regarded as ac-joints and are also rare. The two other sets, the so-called diagonal joints, are strongly developed and in places closely spaced. They cut across the bedding at an angle of about 45° and have a nearly vertical disposition.

In addition, a fifth set of joints was recognised in the quarry face. They are orientated roughly north-south and dip at small angles to the east. Most of them have been widened to open fissures by solution (pl. V).

Two vertical boreholes (M13 and M14) were drilled close to the existing quarry. M13 encountered three major subhorizontal fractures over a section of 7,3 m. These fractures are several centimetres wide and filled with a reddish-brown calcareous sand which caved in on the core barrel so that the hole had to be abandoned prematurely. The same happened to borehole M14 which was drilled 10 m farther west to a depth of 8,4 m. This hole encountered even more fractures per unit interval. Immediately adjacent to the fractures the marble can be described as sugary but the grain interlocking usually improves within a few centimetres. It is clear that these fractures must persist to a considerable depth and at this stage no verdict can be given as to the quality of the marble below the "sphere of surface influence".

(c) Exploitation

The marble from this quarry has been used for tombstones and smallscale decoration of buildings. Although it is relatively coarse grained, it has proved itself suitable for intricate carving. There is only the question as to its resistance to prolonged weathering. The regular arrangement of the north-south and east-west orientated sets of joints should facilitate the extraction of even-shaped blocks. However, recovery of large blocks (exceeding 1 m^3) may lead to considerable wastage. Because of the presence of gently eastward-dipping fractures, quarrying on a floor inclined to the east is advisable. Very large reserves of pure white marble seem to exist in the vicinity of the "Town Quarry". Reserves of easily accessible stone are estimated to amount to more than 10 000 tons per metre depth.

7. Grey Banded "Zebra" Marble at Capra Hill

(a) Location and Previous Work

The deposit (loc. 30, fold. 1 and fold. 4) lies approximately 3 km northwest of Karibib and can be reached by taking the farm road that passes the homestead on Karibib 54. Large-scale exploitation of the marble was undertaken before World War I and at least 5 000 m^3 of rock was removed from the main quarry. Several work faces were cut by wire saw.

Folder 4 is based on data kindly supplied by Ohlthaver and List Trust Co. Ltd. of Windhoek.

(b) Geology

The "Zebra" marble is developed over a width of 20 to 50 m within the grey banded type and can be followed for several hundred metres along strike. It occurs in a tightly folded area where steep dips prevail. The "Zebra" marble is a banded rock with alternating white and grey layers which are between 1 and 20 mm wide, although they are generally in the order of 5 mm (pl. VIII and IX). The grey bands have different shades which vary from light bluish-grey to almost black. The banding may be slightly bent or strongly crumpled, the most intense crumpling being noted in the cores of folds. The average grain size lies between 0,25 and 0,5 mm but the darker bands are usually finer. Impurities in the form of pyrite are also restricted to the darker bands.

The "Zebra" differs from the previously described "Herero" marble in that it is lighter in appearance; the "Herero" is also more intensely folded with finer banding.

Two main sets of joints are developed in the vicinity of the principal quarry. Those striking roughly north-south are the more prominent and can be regarded as ac-fractures. The second set strikes northwest. All the joints are relatively widely spaced.

(c) Exploitation

The "Zebra" marble has a very attractive pattern which should be suitable for large-scale interior decoration of buildings. This deposit could be seriously considered for exploitation because it has the following advantages: (i) Proximity to Karibib; (ii) absence of severe jointing; (iii) minimal weathering of the rock in the exposure area. In addition, two other varieties of marble which occur in the immediate vicinity, namely a white (loc. 31, fold. 1) and a flamed one, could probably be developed at the same time).

Reserves of easily accessible material are estimated as follows:

"Zebra" marble	-	more than 20 000 tons per metre depth
Flamed marble	-	more than 1 200 tons per metre depth
White marble	-	more than 5 000 tons per metre depth.

8. White Marble on Man Repos (ptn. 3 of Navachab 58)

(a) Location and Previous Work

The deposit (loc. 34, fig. 5 and fig. 8) lies approximately 20 km southwest of Karibib. It can be reached by driving from Karibib towards Anschluss for about 10 km and then turning west on to a fairly good farm road. The nearest railhead is Karibib.

The Mon Repos deposit was worked by Robertsons Stone (Tvl.) (Pty) Ltd. between about 1953 and 1956. A slot 18 m long by 1,5 m wide and 2 to 5 m deep, as well as two quarry faces 25 and 12 m long and from 1 to 6 m high, were cut by wire saw. The quarry is situated in the nose of an anticlinal fold. Marble blocks exceeding 3 tons were cut, trimmed and railed. Subsequently Marble Lime and Associated Industries Ltd. worked the same deposit from July 1967 until March 1969, producing about 800 tons of marble. According to this company, high transport costs and other problems caused operations to be unpayable. The marble proved to be very irregular as far as the veining and general colour were concerned, making the matching of slabs difficult.

Figure 8 is based on data kindly supplied by Ohlthaver and List Trust Co. Ltd. of Windhoek.

(b) Geology

The deposit belongs to the Karibib Formation of the Swakop Group. The strike of the beds is roughly east-west, but turns to a northeasterly direction in the eastern portion of the area mapped. The dip is to the south of southeast and ranges from 40 to 75°.

The principal rock-type occurring at and in the vicinity of the quarry is a white marble with occasional light-grey, pink or cream-coloured stains and streaks. It consists of 30 to 50 per cent of dolomite. Intercalations of cherty ferruginous marble, which stand out as prominent brownish-weathering ridges, are not uncommon. On fresh surfaces these layers appear as buff-coloured indistinct streaks in an off-white background. In addition to these streaks, which indicate the bedding of the rock, irregular blotches of cherty material up to 10 cm in diameter occur. Tremolite is a very common accessory and is present in patches or as individual needles up to 3 cm long.

The rock is massive and wholly crystallised; the grain-size varies between 0,125 and 0,5 mm. Due to its relatively high silica content the marble is hard and tough and cutting will therefore be difficult. Although it polishes fairly easily, the impure portions take a less good polish and therefore contrast with the gloss of pure portions. There is no prominent regular jointing developed in the quarry area; only a few fractures parallel to the bedding or cutting across it were observed and many of them are regarded as hair-line cracks. Several pronounced horizontal cracks 1 to 2 m below surface are apparent in the quarry faces. They are believed to be due to weathering. Other weathering effects on the marble are virtually negligible.

(c) Exploitation

The modest jointing, the grain size, pattern and hardness of the marble render it suitable for the decoration of buildings although, in the past problems were apparently experienced in matching colours and patterns of slabs. The slope of the ground and the fresh nature of the surface material contribute to an excellent quarry site. Distance from rail, however, is a distinct disadvantage. The reserves of easily accessible cherty marble are estimated to be several thousand tons per metre depth.

F. PHYSICAL BEHAVIOUR OF THE KARIBIB MARBLES*

In order to get some indication of the physical behaviour of the Karibib marbles, 30 samples from a number of shallow boreholes were submitted to the National Building Research Institute in Pretoria for examination. The scope of this work was very limited and the samples submitted cannot be considered as fully representative of the occurrences that were sampled.

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* Sections contributed by the National Building Research Institute of the Council for Scientific and Industrial Research, Pretoria, are indicated by an asterisk.

To supplement this investigation by the N.B.R.I., the second author briefly visited the cemeteries at Swakopmund, Karibib and Windhoek to see how marble tombstones have stood up to exposure over several years.

1. Description of Samples*

The following cores were submitted to the N.B.R.I.:

Sample No.	Borehole no. and intersection	Description of marble
1	M1 (Navachab Quarry) 0,60-0,78 m	Fairly coarse-grained white marble. Both ends of the core were friable and sugary.
2	M1 (Navachab Quarry) 4,15-6,40 m	Fairly coarse-grained white marble. The ends of the cores were soft and the edges broke away and crumbled when samples were cut and prepared for examination.
3	M1 (Navachab Quarry) 10,35-10,73 m	Fairly coarse-grained white marble with occasional light-grey bands. Very soft and friable and "sugared" when samples were prepared for examination. Not examined further; weathered and completely unsuitable as a dimension stone.
4	M2 (Navachab Quarry) 4,45-4,69 m	Fine to medium-grained white marble with occasional white wollastonite crystals
5	M2 (Navachab Quarry) 6,57-6,74 m	Fine to medium-grained white marble with occasional white wollastonite crystals. Tends to be friable.
6	M3 (Navachab Quarry) 2,60-2,97 m	Fine to medium-grained white marble changing to light-grey in some places. The white portions were very soft while the grey portions were much harder. This section of the core was not further examined because it is regarded as unsuitable as a dimension stone.
7	M3 (Navachab Quarry) 4,95-5,42 m	Medium-grained greyish-white marble, fairly dense but tends to "sugar" when cut in thin sections.
8	M3 (Navachab Quarry) 6,70-7,07 m	Medium-grained greyish-white marble, fairly dense and hard.
9	M5 ("Herero")	Fine-grained grey banded marble. The dark-coloured bands appear to be less dense and had weathered in places. Not examined further.

Sample no.	Borehole no. and intersection	Description of marble
10	M5 ("Herero") 2,80-3,25 m	Fine to medium-grained grey banded marble, slightly weathered. Whitish-pink stripes cut across the core. These stripes consist of light-coloured calcite crystals.
11	M5 ("Herero") 7,30-7,70 m	Banded grey marble, somewhat fractured.
12	M5 ("Herero") 13,55-14,15 m	Fine-grained banded grey marble. Light-coloured calcite veins cut across the core at 45°. These veins appear to be weak zones as the core cracked easily here.
13	M5 ("Herero") 16,30-17,20 m	Fine-grained banded grey marble showing a slight pinkish tint in places. Three clearly developed white calcite veins cut across the core at about 45°.
14	M5 ("Herero") 19,75-20,30 m	Fine to medium-grained banded grey marble showing a distinct pink colour. This section appears harder and denser when compared with samples 9, 10, 11, 12 and 13.
15	M6 ("Damara") 0,90-1,45 m	Fine-grained banded grey and black marble showing a pinkish tint in places. A number of white calcite veins cut across the core. In general the marble is slightly weathered and cracks appear to coincide with the black bands.
16	M8 (Dernburg Hill) 0,80-1,40 m	Medium-grained greyish-white marble, slightly weathered at the top end of the core.
17	M8 (Dernburg Hill) 4,10-4,85 m	Medium-grained greyish marble showing fine random cracks. Not further examined.
18	M8 (Dernburg Hill) 10,10-11,00 m	White marble showing light-grey areas. Towards the 11,00-m end the marble becomes coarser grained and more white. Fine random cracks appear on this section of the core.
19	M8 (Dernburg Hill) 14,35-15,00 m	White marble with numerous light-brown to pink lines. These lines follow no pattern and appear to be cracks. The core broke in two places during handling and at these

Sample No.	Borehole no. and intersection	Description of marble
19 (contd.)		positions appears to be friable. Not further examined.
20	M8 (Dernburg Hill) 17,50-18,10 m	Light grey- white marble, fairly uniform in texture and free of lines when compared with sample 19.
21	M9 ("Esserando") 2,0-2,50 m	Orange-pink medium-grained marble with slightly darker coloured lines. These look like small cracks and follow no definite pattern.
22	M9 ("Esserando") 8,80-9,40 m	Greyish-pink marble with numerous darker coloured lines.
23	M9 ("Esserando") 13,20-13,70 m	Slightly lighter in colour than No. 22. In places the marble is white. Numerous orange-brown lines (hair-cracks) cut across the marble. At the 13,70-m end the marble tends to "sugar" and is fairly soft and friable.
24	M9 ("Esserando") 18,70-19,75 m	Light-coloured (pink/white) marble changing to white in depth. Number of lines (hair-cracks) appears to decrease with depth. Marble appears to be soft and slightly weathered.
25	M11 (Mathildenberg) 2,05-3,00 m	Medium-grained orange-pink marble with darker coloured brown-orange lines which cut across the core at about 60°. The marble at 3,00-m depth is weathered and soft.
26	M11 (Mathildenberg) 7,30-8,45 m	Medium-grained orange-pink marble similar to No. 25. Fewer brown lines are present and it appears to be much harder and fresh.
27	M12 (Okawayo breccia) 8,60-9,10 m	Coarse-grained whitish marble with occasional large white crystals and soft porous limestone inclusions. The inclusions make the marble unsuitable and it was not further examined.
28	M13 ("Town Quarry") 4,73-5,55 m	Medium-grained white marble.
29	M14 ("Town Quarry")	Fine to medium-grained white marble which tends to "sugar" towards the 0,95-m end.

Sample No.	Borehole no. and intersection	Description of marble
30	M14 ("Town Quarry") 6,40-7,00 m	Fine to medium-grained white marble, soft and friable at natural parting planes in the core.

2. Experimental Work*

Samples were cut and prepared from the cores and the following proper ties were determined. Samples of Carrara marble were used as a control.

(a) Water Absorption

The samples were dried in an oven set at 105° C. They were then cooled in a desiccator, and weighed. Thereafter the samples were immersed in distilled water for 24 hours, the superficial water wiped off, and again weighed. In order to saturate the samples completely they were placed under water in vacuum for 6 hours. The table shows the percentages of moisture absorbed by the marble samples.

MOISTURE ABSORPTION OF MARBLES FROM KARIBIB DISTRICT

Borehole no.	Sample no.	A*	B**
M1	1	0,09	0,10
M1	2	0,10	0,10
M2	4	0,12	0,12
M2	5	0,11	0,11
M3	7	0,12	0,12
M3	8	0,12	0,12
M5	10	0,26	0,26
M5	11	0,12	0,12
M5	12	0,16	0,17
M5	13	0,17	0,17
M5	14	0,26	0,26
M6	15	0,13	0,13
M8	16	0,08	0,08
M8	18	0,12	0,12
M8	20	0,12	0,12
M9	21	0,15	0,15
M9	22	0,17	0,17
M9	23	0,22	0,22
M9	24	0,18	0,18
M11	25	0,21	0,21
M11	26	0,21	0,22
M13	28	0,09	0,09
M14	29	0,10	0,10
M14	30	0,14	0,14
Control sample (Carrara marble)		0,08	0,08

* Water absorption obtained by immersion in cold water for 24 hours (percentage by weight of dry rock).

** Water absorption obtained by saturation with water under vacuum (percentage by weight of dry rock).

(b) Compressive Strength

Samples were cut from the cores and then dried in an oven at 105° C to constant weight. They were then cooled in a desiccator and thereafter tested for compressive strength. The results are shown in the table.

COMPRESSIVE STRENGTH OF MARBLES FROM KARIBIB DISTRICT

Sample no.	Borehole no.	Intersection in metres	Compressive strength (N/mm^2)
1	M 1/73	0,60 - 0,78	166
2	M 1/73	4,15 - 6,40	109
4	M 2/73	4,45 - 4,69	136
5	M 2/73	6,57 - 6,74	141
7	M 3/73	4,95 - 5,42	106
8	M 3/73	6,70 - 7,07	93
10	M 5/73	2,80 - 3,25	63
11	M 5/73	7,30 - 7,70	62
12	M 5/73	13,55 - 14,15	71
13	M 5/73	16,30 - 17,20	54
14	M 5/73	19,75 - 20,30	55
15	M 6/73	0,90 - 1,45	42
16	M 8/73	0,80 - 1,40	41
18	M 8/73	10,10 - 11,00	70
20	M 8/73	17,50 - 18,10	53
21	M 9/73	2,0 - 2,50	38
22	M 9/73	8,80 - 9,40	22
23	M 9/73	13,20 - 13,70	108
24	M 9/73	18,70 - 19,75	104
25	M11/73	2,05 - 3,00	24
26	M11/73	7,30 - 8,45	26
28	M13/73	4,73 - 5,55	50
29	M14/73	0,55 - 0,95	49
30	M14/73	6,40 - 7,00	31
Control sample (Carrara marble)			73

(c) Resistance to Salt Crystallisation

Accelerated weathering, using the sodium sulphate crystallisation test, was conducted. Specimens were cut from the cores, dried, weighed and immersed in a 14 per cent solution of sodium sulphate for 16 hours. After this period of soaking they were again dried in an oven at 105° C for 8 hours. After 15 cycles of immersion in sodium sulphate and drying they were weighed and closely examined. In general the marbles behaved very well and they should be regarded as relatively resistant to deterioration by salt crystallisation.

(d) Resistance to Thermal Shock

The same samples that were used for the determination of water absorption were used. for this purpose. They were heated in an oven set at 105° C for one day. and then cooled rapidly by dropping them into cold water. After 20 cycles of heating and cooling all the samples were unaffected and sound.

3. Discussion of Results

Judged by the experimental results it seems that the Karibib marbles generally compare favourably with the Carrara marble that was used as a control, at least as far as this limited examination is concerned. They are dense and have a very low water absorption. For this reason they are resistant to salt crystallisation.

Their compressive strength is considered as adequate and in some instances far superior to that of the control. As a further comparison, Kessler, 1919 (quoted by Bowles, 1958), gives the average compressive strength for each of nine commercial marbles produced in the U.S.A. These figures range between 74 and 126 N/mm^2 with a mean value of 97 N/mm^2 (1 N/mm^2= 145 p.s.i.).

Samples from boreholes Ml, M2, M3 (all Navachab Quarry), M5 (“Herero”), M11 (Mathildenberg), M13 and M14 (both “Town Quarry”) failed in a peculiar way under compression on reaching the breaking load. Whereas the Carrara marble and some of the Karibib marbles fractured and splintered, those mentioned above, which include most of the white marbles, collapsed completely leaving a heap of loose sugary grains. It is known that certain marbles tend to “sugar” but the reason for this is not known as yet.

It would therefore appear that the high compressive stress values recorded for some of the marbles could be misleading when taken as such. Other factors to be taken into account include the mode of failure and the presence or absence of potential fractures, i.e. tight “hair-lines”, in the tested samples. In this way a fracture-free but sugary marble may record a higher compressive strength value than another specimen with a hair-line crack though otherwise sound.

To sum up, in addition to physical tests, it is important to take note of other factors, such as the way the marble weathers in outcrop. The marbles that collapsed under compression should be regarded as suspect as building stones for exterior use because prolonged exposure is likely to cause deterioration. Samples from boreholes M8 (Dernburg Hill) and M9 (“Esserando”) are considered suitable as building stones for both interior and exterior use. In the case of borehole M6 (“Damara” breccia), the size of the sample tested might well have been smaller than that of an individual clast, so that nothing conclusive can be deduced. However, from field observations it would appear that this marble should only be used for interior decoration. (The reader is also referred to section II D 2 and II E of this publication for additional field data on all the above mentioned marbles.)

It should also be pointed out that, for various reasons, no cores were obtained from several other promising marble occurrences like the “Rote Brekzie” at Dernburg Hill, the “Zebra” of Capra Hill, the flamed marbles which occur at many localities, and the white marble of Mon Repos. Tests conducted by the N.B.R.I. on hand-specimens indicated that these varieties are in no way inferior to those listed in tables 1 and 2. From field observations it would appear that the flamed marbles would probably be one of the most durable marbles available from the Karibib District.

4. Weathering of Tombstones

At Swakopmund it was found that all marble tombstones, irrespective of whether imported or local (quarried at Karibib), were subjected to fairly rapid decomposition. This is due to unfavourable climatic conditions at the coast, viz. fog, salt and wind. Many marble tombstones erected some 50 years ago had to be replaced recently (pl. XVIII).

At Karibib several marble tombstones from the period before 1920 were inspected. They were almost without exception manufactured from medium to coarse-grained white marbles which were taken from various quarries in the Karibib District. In practically every case the stone has stood up quite well to exposure with no obvious signs of “sugaring”. However, some of the memorials which had faint "hair-lines" are disfigured by brownish stains that have developed along these cracks. The same has happened to stone with calc-silicate or pyrite impurities (pl. XIX).

In the old Windhoek cemetery the situation is similar to that at Karibib. It is obvious then that climatic factors are very important when deciding whether or not to use marble for any specific memorial or building.

G. CONCLUSIONS

(i) Many varieties of marble occur in the vicinity of Karibib. In addition to black, grey and white, coloured varieties which are mostly brown, reddish or yellowish are present. The rocks are either massive and unicoloured, banded (straight or plicated), or flamed. Locally, coarse marble breccias have developed.

(ii) Many of the marbles, at least in hand specimen, seem to be of good quality. They display beautiful colours, vivid patterns and most of them take a good polish. Physical tests conducted on 24 marble samples show that they are dense with a very low water absorption and that their compressive strength is adequate. Nevertheless, the manner in which some of these samples failed under compression is a matter for concern and casts doubt on their use as a building stone for exterior use. It is also obvious that in general there is a large variation in quality, even at the same locality. In some boreholes the marble improved in depth while in others the position was reversed.

(iii) A major problem that will affect dimension stone quarrying is the generally severe jointing. This is related to the intense folding of the strata. In some places the joints are so narrowly spaced that it would be impossible to obtain blocks of marketable size.

(iv) Another factor which detracts from the value of the rock is the presence of impurities. In the area surrounding Okawayo 46 and Okatjimukuju 55 the marble is contaminated to such an extent by quartz and other silicates that it cannot be quarried profitably. Elsewhere these impurities usually occur in small amounts only and do not affect the quality of the rock to a great extent. A quite strongly contaminated marble was in fact quarried at Mon Repos.

(v) Weathering usually reaches to a depth of only a few metres and at many places the rock outcrops are practically fresh. Locally, however, solution fissures and cavities may reach considerable depths; this is particularly the case with the white and the coloured marbles. The position and extent of such solution channels could be very difficult to predict.

(vi) Some varieties of marble cannot be worked on a large scale because reserves are too small; this holds especially for the black and some of the grey marbles. Reserves of coloured varieties can hardly be estimated since the colours change very rapidly.

(vii) Quarrying of banded varieties is risky because they tend to split along the banding. Splitting occurs more frequently along dark pyritebearing bands or in rocks with straight, sharply defined banding.

(viii) Quarrying of most of the coloured varieties also appears risky. They are generally slightly brittle, tend to be closely and irregularly jointed, and contain considerable amounts of impurities locally. In many instances a specific colour is not persistent and the rocks are often cut by solution channels.

(ix) Drilling has indicated that there is little chance of a deposit which looks unsound on the surface (severe jointing, etc.) improving within the first 10 to 20 m. Economical quarrying will therefore be confined to good-quality outcrops.

(x) The most promising marbles, as far as economical exploitation is concerned, would appear to be the following:

Flamed marbles.- Large reserves occur at many places in the immediate vicinity of Karibib-Mathildenberg, Capra Hill, Navachab 58 and Dernburg Hill ("Rote Brekzie"). It is attractive and different effects can be obtained by cutting it in different directions. In general the flamed marble is sound and dense, even at the surface, and joints and solution holes are infrequent. Possibly its only serious disadvantage lies in the fact that it occurs in narrow bands (3-15 m wide). This handicap may be overcome by quarrying the adjacent marbles also, where these are attractive enough, as is the case at Capra Hill and Dernburg Hill.

White marble.- Pure white marbles are usually in demand and for that reason the deposits at the Karibib "Town Quarry" and Mon Repos should be considered, although the distance of the latter from the nearest railhead is a disadvantage. Furthermore, the white marbles from the Karibib area generally tend to "sugar" and they should be treated with some suspicion, especially for exterior use.

White marble breccia.- This variety, which occurs on the northern slopes of Dernburg Hill, would merit further consideration, especially if it could be exploited in conjunction with the overlying black dolomitic marble.

Pink "Esserando" marble.- This type, which occurs at Dernburg Hill, is subject to certain handicaps such as relatively closely spaced irregular jointing. Nevertheless, with its exceptional colour, it warrants further consideration, perhaps as a source of marble for special small-scale decorative purposes.

(xi) From a geological point of view the above-mentioned varieties of marble, as well as some of those discussed in preceeding pages, can be regarded as suitable for use as dimension stone. However, it will be economic aspects, such as steady demand, quarrying costs, quantity of waste, labour and transport costs, that will ultimately determine whether the Karibib marbles can be profitably exploited or not. A full assessment of these factors will be essential for any would-be entrepreneur.

III. MARBLE DEPOSITS IN THE SWAKOPMUND-WALVIS BAY AREA

A. INTRODUCTORY REMARKS AND HISTORY

Walvis Bay, situated on the Atlantic coast, is the main harbour for South West Africa and is well equipped to handle marble blocks for export. During German colonial times Swakopmund had similar facilities and a small quantity of marble from Karibib was actually shipped to Europe. However, the transport costs from Karibib, which lies 175 km inland, raised the price of the blocks considerably. Thus the extensive deposits of marble in the vicinity of the coast soon attracted attention.

Gürich (1910), Hagen (1910) and Wagner (1916) mentioned deposits of yellowish-green marble extending from Swakopmund eastwards, and of other types occurring in the Hamilton Mountains which are situated about 40 km east-southeast of Walvis Bay. Although the various marble deposits were investigated to a certain extent, no quarries were established and it was only recently that Marmorwerke Karibib started to quarry a green type on a small scale some 20 km east of Swakopmund.

The eastern portion of the area under review was mapped by Smith (1965) and his report and geological map have been used as a starting point for the present investigation. In 1964 the marbles immediately east and northeast of Swakopmund were investigated by the Geological Survey and it was conservatively estimated that $20x10^6$ tons of the easily accessible white marble within 5 km from the town is suitable for the manufacture of cement (Heath, 1964).

B. PRESENT INVESTIGATION

An area of about I 500 km^2, extending from the Atlantic coast to Rössing Mountain, the Hamilton Mountains and Swartbankberg in the east, and bounded by the Kuiseb River in the south and latitude 22° 30' in the north, was mapped on aerial photographs to a scale of 1:36 000. Subsequently figures 9 and 10 were compiled.

C. DESCRIPTION OF THE MARBLE DEPOSITS

I. Morphology

The area lies on the Namib Plain, which extends up to 100 km inland from the coast. Incised by the Swakop River and its tributaries, interrupted by inselbergs like the Rössing Mountain, and transgressed by numerous dolerite dykes and low ranges of marble hills, the plain is not very well developed in the area to the east of Swakopmund. South of the Swakop River it is more continuous, although it is interrupted by long marble ridges and inselbergs, the more prominent of which are the Hamilton Mountains and Swartbankberg, respectively some 40 and 50 km southeast of Walvis Bay.

2. Geology

Apart from Tertiary to Quaternary deposits and numerous dolerite dykes of post-Karoo age, the area is mainly underlain by strongly folded and regionally metamorphosed rocks of the Swakop Group, which can be subdivided as shown in paragraph II C 2.

The sediments of the Hakos Subgroup, which in this area follow conformably on those of the Nosib Group, consist of quartzite, marble and amphibole-biotite schist. The thickness of the marble varies widely from place to place reaching a maximum of some l40 m.

Marble of the Hakos Subgroup was found only at Rössing Mountain where it forms two long bands up to 75 m thick representing the limbs of a refolded anticline (fig. 9). Light-grey to white and grey banded varieties of a medium to coarse-grained tough rock and thin layers of a green variety are developed.

The bulk of the marble is, however, correlated with the Karibib Formation of the Khomas Subgroup. In addition to marble, the Karibib Formation contains minor biotite schist and amphibole schist. East of the area investigated the marble may form a number of individual bands separated by layers of schist, but in the area itself it occurs as a single sequence of massive or thickly bedded marble/up to 500 m thick. Within this sequence only a few layers of schist or cherty material are developed.

The marble is predominantly white and grey in colour, but a green variety which usually occurs in thin layers is also quite common. Other varieties display red, beige and brown hues. Except for the green variety which contains numerous impurities such as forsterite, tremolite, diopside and sphene, and which in places may rather be termed a calc-silicate rock, the marble is comparatively pure. Some grey varieties occasionally include some hydrogen sulphide and freshly fractured rock emits a foetid smell. The proportions, of calcite and dolomite in the marble very widely. Certain white varieties contain less than 1 per cent dolomite; the bulk, however, contains 50 to 90 per cent of this mineral and is therefore dolomite marble.

3. Tectonics and Metamorphism

The structural pattern is defined by a series of northeast-trending synclines and anticlines. At several localities, however, fold-interference patterns are apparent, displaying two superimposed axial directions. These complicated structures, which were observed at Rössing Mountain and to the west of it (fig. 9), are assumed to be caused by the refolding of earlier northwest-trending folds.

To be distinguished from these, are certain dome-like structures, e.g. 20 km east of Swakopmund on the Swakop River (fig. 9) and at Swartbankberg (fig. 10), which originated through distortion of northeast-striking folds by extension of the strongly deformed rock parallel to the major fold axis during the same deformation phase.

The marble often forms long narrow outcrops with the rocks dipping steeply towards the northwest or southeast (fig. 10). These outcrops, which in places are several kilometres in length, represent the limbs of folds which were stretched and attenuated during tectonic compression, while in the crests and troughs a thickening took place. In the Hamilton Mountains, for example, the thickness of a grey marble layer is some 300 m in the limb, while in the trough it amounts to about 900 m; similar variations were also observed elsewhere. The variation in thicknesses is, however, not due solely to tectonism since comparatively gently folded strata also display this feature. Hence the thickness of the whole marble succession is difficult to estimate although 500 m may be taken as a fair average.

Large-scale faulting is almost unknown in the area. On the other hand jointing, which is intimately related to the folding, can be observed everywhere. Locally the joints are so closely spaced that recovery of marble blocks of marketable size cannot be expected. However, regarding the area as a whole and taking into account the obviously strong folding of the rocks, jointing is comparatively moderate and less prominent than in the vicinity of Karibib. This may possibly be due to the intense metamorphism which in this area reached its climax only after the last deformation phase. While other metasedimentary rocks were transformed into gneiss or granite, the marble underwent further recrystallisation during which some of the joints may have been closed.

In accordance with the high-grade metamorphism, the marble is usually coarse to very coarse grained. Within the whole sequence calcite marbles usually attained the coarsest grain (crystals of up to 20 cm across have been seen) whereas dolomite marbles, particularly when containing siliceous impurities, are much finer with a grain size generally not exceeding 5 mm.

4. Weathering

The main causes of weathering of the marble are incessant changes in temperature, wind, and humidity originating from fog.

Diurnal variations in temperature lead to a gradual destruction of the rock structure near the surface and entail cracking of the rock itself. Besides this mechanical weathering, some chemical weathering may also take place within the cracked portions when condensed moisture from the fog which occurs some 300 nights per year, collects in large amounts upon the surface and soaks into the rock.

The effects of mechanical and chemical processes are more pronounced in marble ridges rising 50 m and more above the flats, e.g. at the Hamilton Mountains and at Swartbankberg. East of Swakopmund the outcrops of marble do not exceed 15 m in height, and in general rise only 1 to 5 m above the surroundings. Their surfaces generally appear solid and smooth as the weathered portions are continuously removed by slope washes during occasional showers of rain and by creep. Eventually strong winds transporting sand and sometimes even gravel, particularly when blowing from the east, smooth the surface and polish them on their northeastern sides.

5. Varieties of Marble in the Area East of Swakopmund

In the area east of Swakopmund, i.e. as far as Rössing Mountain (fig. 9), the following varieties of marble are developed: grey, grey banded white, and green.

(a) Grey Marble

The grey marble occurs only in the Rössing area and in a small outcrop to the south of it (fig. 9). It is a coarse-grained, dirty light-grey (and in places almost white) rock containing some silicate and graphite impurities. It is either tough or friable. At both localities layers of a greenish variety are interbedded with it.

Because of its dull colour and coarse grain this variety is not considered suitable for quarrying as dimension stone.

(b) Grey Banded Marble

This type underlies a large area south and southwest of Rössing Mountain (fig. 9). Being very friable and sugary, its outcrops are flat and only a few isolated rounded hills are preserved. The rock is coarse to very coarse grained and exhibits an indistinct banding caused by an alternation of layers of different grey shades and white; however, as a whole the colour is dull.

Locally hydrogen sulphide is included in the solid rock. The gas is believed to be responsible for a yellow coloration of the calcite crystals, as these portions emit a foetid smell from fresh surfaces. Other impurities in the usually very dolomitic marble are tremolite, diopside, graphite and a little quartz. Chert layers up to 10 cm thick are common. Southwest of Rössing Mountain granite and numerous pegmatites have intruded the marble, which is particularly coarse grained and only very rarely displays any banding.

Due to its coarseness, its sugary texture and the dull colour the grey banded marble cannot be recommended for quarrying.

(c) White Marble

White marble, which in places displays a greyish tinge, occurs extensively in the western portion of the area (fig. 9). It crops out in long broad ridges which usually do not rise more than 10 m above the flats and is generally found in the immediate vicinity of granite. The granite sometimes intruded the marble and generally caused strong recrystallisation of the latter with crystals up to 20 cm across.

Chemical analyses reveal the rock to be a very pure calcite marble containing not more than 3 per cent dolomite on the average. However, at many localities it includes varying amounts of hydrogen sulphide which, when occurring in high concentrations imparts a yellow colour to the crystals (loc. 45, fig. 9). Other impurities are mainly graphite, mica and subordinate iron ore.

Locally the marble shows somewhat darker bands 3 to 10 cm thick; usually, however, banding has been obliterated during the recrystallisation of the rock. In some places thin layers of chert and interbeds of mica schist up to 5 m thick were observed within the sequence.

The white marble is much too coarse grained and friable to be suitable for the recovery of blocks. However, as it contains less than 3 per cent dolomite, it is well suited for the production of cement, and therefore it has been extensively pegged by the South West Africa, Portland Cement Company.

(d) Green Marble

Green marble is restricted to an area extending about 20 km eastwards from Swakopmund and 10 km northwards from the Swakop River (fig. 9). The rock forms narrow ridges, locally rising 15 m and more above the flats, and can be followed for several kilometres continuously. Towards the coast the ridges, which measure up to 75 m across, gradually disappear.

At several localities this medium-grained tough rock exhibits an intense green colour which is due to inclusions of serpentine, an alteration product of forsterite (olivine). The serpentine may be either disseminated throughout the white or grey rock mass or concentrated in distinct layers, giving rise to different varieties of green marble. The unbanded type is virtually a white, light or medium-grey marble with green speckles which may be so numerous and closely spaced that the impression of a green rock is gained. The most frequent banded type consists of alternating coarsegrained white or light-grey layers 2 to 10 cm thick, and less coarsegrained layers rich in serpentine. A disadvantage of all varieties of banded marble is their tendency to split along the banding, which corresponds with the bedding.

All the green marbles contain large amounts of dolomite (up to 90 per cent) and many impurities, amongst others forsterite, tremolite, diopside mica and pyrite. The jointing of the rock is generally moderate. There are, however, localities where strong fracturing is present. Bedding joints are the commonest, particularly in the banded varieties, but ac-fractures, perpendicular to the direction of strike and the plunge of fold axes, also occur frequently.

A greenish-white banded marble, 8 to 10 m thick and with a greyish tinge locally, forms an anticline some 7 km northeast of Swakopmund. The rock is of good quality but the outcrops rise only 0,5 to 1 m above the flats (loc. 46, fig. 9).

Some 5 km farther northeast coarse-grained greyish-green and greenish-white banded marble occurs in a long narrow ridge up to 15 m high. Although the rocks are strongly jointed locally, the recovery of blocks of marketable size should be possible somewhere along this ridge (loc. 47, fig. 9).

The occurrence of green marble most suitable for the recovery of marketable blocks is the one held by Mr. P.O. Petzold of Karibib (loc. 48, fig. 9). The deposit, which forms a ridge rising to some 15 m, is situated about 550 m southeast of Nonidas railway siding approximately 15 km east of Swakopmund. The rocks dip from 40° to vertical and display little folding. The southern margin of the ridge is generally steeper than the northern one which occasionally forms a dip slope. Several north-striking faults with minor dislocations, accompanied by silicification and sideritisation of the marble, were observed at the northeastern end of the claim area. Other zones enriched in chert and siderite are developed parallel to the strike of the rock and are possibly due to strike faulting.

The main type of rock in the claim area is a tough, white to greyishgreen fairly coarse-grained banded marble with grain size ranging from 2 to 10 mm. Banding is obvious but not striking. In weathered portions the green colour tends to be more yellowish, while locally reddish shades occur which are caused by a higher content of iron oxides. The appearance of polished slabs depends on their orientation. Slabs cut perpendicular to the banding present a mottled appearance, whereas those cut parallel to the banding are more evenly coloured.

The marble, which is considered suitable for large-scale quarrying, has been used for the interior decoration of the Swakopmund Post Office (pl. XX).

6. Varieties of Marble in the Area East and Southeast of Walvis Bay

In the area southeast of Walvis Bay (fig. 10) most of the prominences belong to a marble range some 50 km long which starts at Swartbankberg near the Kuiseb River and extends in a northeasterly direction beyond the Hamilton Mountains. The highest portions rise to more than 100 m above the flats.

In this range, unlike the area east of Swakopmund where the different types of marble occur separately, several varieties are normally exposed close together in a single outcrop. From top to bottom the following succession occurs at Swartbankberg and to the west of it:

Biotite schist
Dark-grey marble (15 m)
White marble (10 m)
Grey banded marble (30 m)
Grey and flamed marble; locally brown marble (350-400 m)
Grey banded and flamed marble (150-200 m)
Green marble (25 m)

This sequence may vary somewhat according to local changes in colour, pattern and thickness. The grey banded type, for instance, often loses its banding giving way to a grey or light-grey variety. The green marble, on the contrary, constitutes a rather constant marker horizon near the bottom of the sequence.

The rocks in the area are strongly folded; dips of 70° and more prevail. A considerable percentage of the marble is consequently rendered worthless by intense fracturingo Metamorphism and recrystallisation are less pronounced than in the area east of Swakopmund.

(a) Grey and White Marbles

Two varieties of grey marble are developed in the area; one is fine grained and dark coloured and includes hydrogen sulphide, whereas the other is light grey to almost white and much coarser grained. The latter type may be suitable for block quarrying at one locality in the southern portion of the Hamilton Mountains (loc. 49, fig. 10) where it was found to be very pure and of silvery-grey colour. Unfortunately, strong jointing is apparent at the surface.

Only small occurrences of white marble were encountered in the area.

(b) Grey Banded Marble

Varieties of grey banded marble occur almost ubiquitously in the area, all of them being coarse grained with a tendency to split along the banding. The banding is either broad and indistinct or narrow and sharp. Certain layers often contain hydrogen sulphide which escapes from freshly-cut surfaces. Chert layers up to 5 cm thick are not uncommon.

The banded marble is regarded as unsuitable for block quarrying.

(c) Flamed Marble

The flamed marble is an intraformational breccia. In this area it occurs interbedded in grey or grey banded rock and is restricted to Swartbankberg and the southern portion of the marble range.

At Swartbankberg it forms four ridges up to 3 m high and 10 m wide which can be followed around the whole mountain. Due to strong recrystallisation and tectonic pressure the boundaries between fragments and matrix are usually indistinct and locally the rock is more cloudy than flamed. At other places it is less attractive because fragments of grey marble “float” in a matrix of the same colour.

About 10 km north of Swartbankberg on the eastern side of the marble range (loc. 50, fig. 10) a ridge of a flamed variety about 10 m high provides a good site for a quarry. The rock is solid and comparatively little jointed. Due to severe tectonic stresses the fragments were flattened considerably and the rock, when cut perpendicular to the bedding, appears more banded than flamed However, when cut parallel to the bedding, yellowish-white fragments included in a reddish to brownish-grey matrix can be seen. The rock may be suitable for block quarrying.

(d) Brown Marble

Marble with a beige, reddish or brownish colour was encountered at three localities; two of them are unsuitable for quarrying as the rock occurs either in too small quantities or is too brittle and rich in silica.

The third deposit is situated on the western slope of a hill near the southern bank of the Tumas River (loc. 51, fig. 10). It is a light-grey rock with brown spots and pink and reddish-brown veins; greenish hues occur in places. It forms a ridge from which blocks of marketable size may possibly be recovered.

(e) Green Marble

Green marble is found at many localities in the central portion of the marble ridge. As in the area east of Swakopmund (fig. 9), four main types are developed, namely white and grey, both with green specks, as well as a greenish-white banded and a greyish-green banded variety. In addition, all may have a brownish tinge which gives a total of eight varieties. Virtually all of these are present in a single outcrop some 10 km north of the Hamilton Mountains (loc. 52, fig. 10) where the following sequence of layers, 3 to 10 m thick, is exposed:

Greenish-white banded marble, brownish to greyish-green slightly banded marble, light-grey to greenish-white banded marble, pinkish-white banded marble, greenish-white irregularly banded and cloudy marble, violet to greyish-green banded marble and greyish-green marble.

The deposit is unfortunately not suitable for quarrying, as schist, quartzite and chert layers are interbedded in the sequence.

An occurrence which may be suitable for exploitation was encountered in the northern part of the Hamilton Mountains, immediately south of the main road to Walvis Bay (loc. 53, fig. 10). Here a greenish-white banded rock exhibiting a vivid colour forms a ridge 8 to 10 m high. The joints, which in places are very closely spaced, should facilitate easy cutting of slabs and/or smaller blocks.

Some 3 km farther south a greyish to brownish-green slightly banded marble, which in different layers exhibits more greyish, brownish or greenish hues, occurs. The marble is more than 20 m thick and strongly fractured at the surface.

A pale-green marble occurs on the western slope of the marble range about 2 km northwest of Swartbankberg (loc. 55, fig. 10). The outcrop is some 200 m broad and extends for several kilometres along strike. Large-scale quarrying may be possible.

D. CONCLUSIONS

(i) White, grey, grey banded, brown and green varieties of marble and a sedimentary breccia (flamed marble) are developed in the area east and southeast of Swakopmund and Walvis Bay.

(ii) Of these the green variety could be considered as of economic value. Good outcrops which may be suitable for large-scale quarrying occur within a reasonable distance from Swakopmund and Walvis Bay. The rock exhibits a vivid colour and is either banded or uniformly coloured.

(iii) Most of the other varieties occurring in the area are either too coarse grained, too contaminated by impurities, or too dull in colour to be suitable for large-scale dimension stone quarrying.

(iv) The extremely coarse-grained white marble which occurs east of Swakopmund can be used as a raw material for the production of cement.

IV. MARBLE DEPOSITS IN THE SOUTHERN WINDHOEK DISTRICT

A. INTRODUCTORY REMARKS

Windhoek, the fastest growing centre in South West Africa, provides an important market for marble and building stone. In an effort to keep transport costs low, prospecting for marble deposits suitable for quarrying commenced at an early date in the neighbourhood of the city. Up to the present no significant block quarrying has taken place although marble from several localities is being crushed by Peralin (Pty.) Ltd for the manufacture of terrazzo, marble roughcast and various other products.

The area south of Windhoek was mapped by Schalk and Hälbich of the Geological Survey. Their unpublished map (1965) and a report by Gevers (l934) served as bases for the present work which concerns the area shown on fig. 11.

B. GENERAL DESCRIPTION OF MARBLE DEPOSITS

1. Geology

In this area marble is developed mainly at three different stratigraphic levels within the Swakop Group. Most widespread and prominent of all is a marble band up to 120 m thick in the lowest portion of the Hakos Subgroup. This band is particularly well developed in the eastern portion of the area where it crosses the main road to Dordabis several times on Voigtland 77, Hohewarte 76, Hohenau 81, Brack 83, Waldburg 82, Elisenhöhe 88, Tsatsachas 87 and Coas (portion of Hatsamas 92).

It comprises mainly grey and grey banded varieties which are contaminated in some places by various silicates and include interbeds of sandstone, slate and quartzite. Within the Hakos Subgroup this basal layer is followed by several marble bands. These seem to be present only in the southern portion of the area, where they usually form lenses within schist. Farther eastward they were either removed by intraformational erosion or were never developed.

The Hakos Subgroup is overlain by a succession of conglomerate, quartzite and amphibolite with interbeds of itabirite, a succession which probably corresponds to the Chuos diamictite in the Usakos-Swakopmund area, and which locally contains lenses of impure marble, e.g. on Voigtland 77 and Hohenau 81.

In this area the equivalent of the Karibib Formation, which forms a thick marble sequence in the Karibib District, is only of minor importance as far as the development of marble is concerned. This marble occurs on Hohenau 81, Hohewarte 76 and Voigtland 77, whence it trends in a southwesterly direction via Finkenstein 71 and Klein Windhoek 70 towards Kruin Siding. The marble is dirty white or grey banded and rich in siliceous impurities.

On Finkenstein 71 and Klein Windhoek 70 a band of dirty-grey highly siliceous marble is found interbedded in the schistose succession of the Khomas Subgroup. This marble possibly concluded the deposition of carbonate rocks within the Swakop Group.

The rocks in the area are generally intensely folded and strongly sheared. The marble in particular, being an incompetent layer within a succession of quartzite, schist and amphibolite, shows distinct traces of strong tectonic stresses, i.e. isoclinal folding, brecciation, mylonitisation and shearing parallel to the strike. The thickness of the marble is therefore difficult to estimate as tectonic duplication or multiplication may be present.

The marble of the Hakos Subgroup seems to attain its maximum thickness in the vicinity of Stolzenfeld 89 where some 120 m of slightly disturbed rock is exposed. The greatest thickness of marble which can be regarded as the equivalent of the Karibib Formation in this area is estimated to be not more than 80 m, as observed on Hohenau 81. The marble band found in the Khomas schist attains a maximum thickness of some 20 m only (Voigtland 77). It must be emphasised that the figures quoted refer to maximum thicknesses which may dwindle rapidly due to primary thinning, faulting or contemporaneous slumping during which portions of the marble were removed from their original position and redeposited as breccias.

2. Varieties of Marble

(a) Grey Banded Marble

The most abundant variety is a medium to coarse-grained grey banded marble. Individual bands display different shades of a dirty, medium to light-grey colour and rarely also a pure white. Thin layers of cherty material or interbeds of graphitic schist and quartzite are not uncommon.

A thin coating of mica and talc on bedding planes frequently imparts a platy structure to the rocko In addition, the tendency to split along the bedding (which parallels the banding) is often promoted by shearing parallel to the strike.

The grey banded marble is largely contaminated by impurities among which actinolite, diopside, muscovite, talc, graphite and quartz are the most common. At many places the rock includes small amounts of hydrogen sulphide, which is emitted from fresh surfaces. Locally portions of the rock are particularly enriched in hydrogen sulphide and are yellow in colour. This is frequently seen on the southern slopes of Humansberg on Waldburg 82 (loc. 56, fig. 11), on Elisenhöhe 88 (loc. 57, fig. 11) and on Kransnek 269 (loc. 58, fig. 11).

(b) Grey and White Marbles

In addition to the grey banded variety, which is found almost ubiquitously, a unicoloured grey or white marble is also of some importance in the area. This type was either primarily deposited as a layer of grey or white rock or may have developed from a banded variety through extensive recrystallisation, during which the banding became indistinct and finally disappeared completely.

The white and grey marbles are generally medium to coarse grained, strongly contaminated by impurities and display a dirty colouro Locally, e.g. on Hohewarte 76, they are very rich in talc, being talc schist rather than marble, and on Hohenau 81 a tremolite-rich white marble (also containing some chalcopyrite) is found (loc. 59, fig. 11). At many localities the marble has a brown weathered crust, the colour of which is due to a certain amount of finely dispersed iron oxides. In strongly jointed deposits, e.g. 1 km north of the farm-house on Waldburg 82, brown sideritic veins cut across the otherwise white marble.

The unicoloured varieties are generally more massive than the banded ones; however, at many places jointing and fracturing are so prominent as to render the white and grey marbles unsuitable for large-scale block quarrying. This also applies to a dark-grey to black marble with quartz impurities which is quarried by Peralin (Pty.) Ltd about 1 km west of Leutwein Siding for marble crush.

The only deposit of white marble which appears to be suitable for block quarrying is found on Gocheganas 26 (loc. 60, fig. 11). This occurrence will be described in more detail later.

(c) Reddish and Brownish Marbles

Deposits of reddish and brownish marbles are of rather limited extent in this area and most of them are not considered suitable for large-scale block quarrying.

On the boundary between Koanus 121 and Otjimukona 120 (loc. 61, fig. 11) a deposit of brown, greyish-brown and beige marble, together with a white and dirty-white variety, is developed. The brownish type is medium grained and tough. It is thinly bedded and displays a slight banding which, in places, is accentuated by layers rich in biotite and hematite and by thin cherty interbeds. Mainly because of these cherty layers the rock tends to part into flat slabs. In addition, several sets of narrowly spaced joints are prominent on the surface, cutting the rock in such a way that only small portions of the deposit will be suitable for the recovery of sound blocks of marketable size.

A light reddish-brown marble occurs about 1 km south of the boundary between Brack 83 and Elisenhöhe 88 (loc. 57, fig. 11) on both sides of the main road to Dordabis. The rock is medium grained and not very hard. Its colour is caused by finely dispersed hematite which may be more concentrated in certain layers or portions, thus leading to banding or irregular staining. In general the marble is massive, although in places it tends to split along bedding planes. Impurities other than hematite and a small amount of quartz are rare. The reserves appear to be small as the reddishbrown variety forms lenses within white and grey marble.

Near Bergland Siding on Nabitsaus 263 (loc. 62, fig. 11) reddish-brown and off-white varieties overlain by a large body of a grey marble occur in the nose of a fold. The reddish-brown variety, which locally displays yellow and violet-brown hues, is not persistent along strike but forms lenticular bodies up to 20 m thick and 100 m long within an impure white marble. The, medium to coarse-grained rock is intensely folded and exhibits a platiness which is mainly caused by cherty layers and a coating of mica and talc on the bedding planes. Near the surface the reddish-brown marble is extremely friable. The deposit is not suitable for large-scale block quarrying, although it is exploited by Peralin (Pty.) Ltd for marble crush.

A fine to medium-grained deep reddish-brown to beige marble is known from Gocheganas 26 (loc. 63, fig. 11). The colour, originating from iron oxides included in the rock mass, is variable. The marble deposit contains abundant siliceous impurities, particularly quartz, mica, talc and actinolite, while a considerable portion is rendered worthless by solution channels and cavities which are partly filled with calcite and silica. It is also bounded on three sides by faults, parallel to which shear zones are developed within the marble. In addition, it is cut by prominent joints striking in a northeasterly direction. The reserves of the entire deposit are estimated to be about 8 000 tons per metre depth but much overburden will probably have to be removed first before block quarrying can be considered. Any such an attempt should be preceded by test drilling.

C. THE MORE IMPORTANT DEPOSITS

1. The White Marble on Gocheganas 26

(a) Location and Previous Work

The deposit (loc. 60, fig. 11 and fig. 12) is situated approximately 35 km south of Windhoek. It can be reached by following the tarred road to Rehoboth for about 30 km and thereafter turning east into a good farm road. The nearest railhead is Leutwein Siding but at present marble products are loaded at Aris Siding which lies about 7 km to the north-northwest.

The marble crops out in five hillocks 3 to 15 m high which are situated along a semicircle about 1 km in length (fig. 12). Loose blocks from the central hillock were recovered on a small scale by the firm Gramaham of Windhoek between about 1927 and 1957. They were used mainly for the manufacture of tombstones. At present (1974) the marble is being worked at the same hillock by Peralin (Pty.) Ltd and used for the production of terrazzo, roughcast and various other products.

(b) Geology

The white marble deposit forms a lens within a succession of biotite schist and red quartzite of the Hakos Subgroup. It occurs in the nose of a syncline which plunges steeply to the southwest.

The pure white dolomite marble is medium grained and generally tough; in some portions of the deposit, however, it is extremely friable and sugary, as for instance on the eastern slope of the central hillock. On the northern slope of the same rise the rock is spoilt by small black spots of iron oxide. Locally manganese oxides form tiny dendrites on bedding and fracture planes. Other impurities which occur in variable amounts are mica, talc and quartz; they are more concentrated in the southern and northern portions of the deposit.

Two main sets of joints are present throughout the deposit, one striking about north, the other one roughly east. Two less prominent sets of joints striking northwest and northeast are locally developed. Where all four sets are found together the marble is too closely fractured to be suitable for the recovery of blocks of marketable size. Generally, however, the spacing of the joints ranges between 0,5 and 1,5 m. The marble on the northern slope of the central hillock is sound and only slightly fractured. On the eastern slope of the same hill the rock is cut by a prominent shear zone which renders this portion of the deposit worthless (fig. 12).

Due to the arid climate, the marble is weathered only slightly and to a shallow depth. Its surface is generally solid; in some portions the texture of the rock has been weakened resulting in a sugary appearance. Tombstones manufactured from sound blocks and erected more than 40 years ago in the old Windhoek cemetery show practically no signs of weathering.

(c) Exploitation

The white marble of Gocheganas 26 is of fairly good quality and those portions which are free from black spots and are not sugary are regarded as suitable for block quarrying. This holds especially for the northern portion of the central hillock, although it is unknown whether the blasting that is presently employed to obtain marble for crushing has had any detrimental effect on the deposit.

At all five hillocks the marble could easily be produced from open-cast workings. The pure white marble will probably be suitable for exterior and interior decoration, for tombstones and possibly also for statuary work.

The reserves of easily accessible pure white marble are estimated at 3 500 tons per metre depth, whereas the reserves of the deposit as a whole amount to some 140 000 tons per metre depth. The deposit is only a few kilometres from the nearest railhead.

2. The Marble Deposits at Lübbertberg

(a) Location

One of the most extensive marble deposits in the Windhoek District occurs at Lübbertberg which lies about 80 km southeast of Windhoek and 15 km northwest of Dordabis. It can be reached by following the tarred road to the J.G. Strijdom Airport for some 25 km and then turning south on to a good gravel road.

(b) Geology

Apart from two minor intercalations of schist and quartzite, Lübbertberg consists of marble which, together with some underlying schist, represents the basal portion of the Hakos Subgroup. The rocks are folded and form a synclinorium which is partly overturned to the south (fig. 13). Although less sheared than the surrounding rocks, most of the marble is unsuitable for the recovery of blocks of marketable size due to the presence of closely spaced fractures.

White, grey, pink and brown varieties of marble are developed at Lübbertberg, but the predominant type consists of a mixture of them all: a dirty, light brownish-grey rock.

White marble.- A dirty-white sugary and slightly siliceous marble is developed in the core of a syncline in the highest portion of Lübbertberg. This type, which forms the highest member of the marble succession, is not suitable for quarrying.

Grey marble.- This variety was found at the base of the succession and in thin bands at higher levels. It is either unicoloured light grey to dark grey or irregularly banded. In places a distinct schistosity is developed. The silica content is generally low.

Pink marble.- Pink to beige-coloured marble occurs at several localities, either forming persistent layers or lens-like bodies within the light brownish-grey type. At locality 64 (fig. 13) on the southern slope of Lübbertberg, a layer of fine-grained intense pink slightly sugary rock is developed. Although solid layer's were observed, the rock tends to split along bedding planes containing talc. The colour is not persistent along strike but may change to purple, brownish grey or beige. Because of its tendency to split into slabs, the recovery of blocks of marketable size will be difficult.

A lens of pink marble was found at locality 65 (fig. 13). It has a strongly developed platy structure due to sericite coating the bedding planes. It should be possible to recover fairly large slabs 3 to 5 cm thick from the deposit, but due to the small reserves of intensely coloured rock, the occurrence is not suitable for large-scale quarrying.

Brown marble.- Light-brown and dark-brown varieties are mainly developed in the western portion of Lübbertberg. They are fine to medium grained and usually highly siliceous. The colour may change rapidly and lenses of purple marble rich in siderite may occur. At all localities the rock is strongly fractured on the surface and the recovery of larger blocks will hardly be possible.

Brownish-grey marble.- The bulk of the marble is brownish grey to light brownish grey in colour. However, within this range of colours the rock may locally attain more yellowish, beige, pink, reddish, brownish or greyish hues and may either be unicoloured or show a more or less distinct banding. A feature of the whole suite of brownish-grey marbles is a brown weathered crust by which they can be distinguished from grey varieties. The rock is usually fine grained and brittle and contains a certain amount of silica. Almost everywhere a strong fracturing is apparent and locally the rock has developed a pronounced platy structure. The marble has a less attractive colour and its tendency to split along bedding planes will render the quarrying of blocks difficulto

(c) Conclusions

Although vast amounts of attractive pink, brown and brownish-grey marbles are present at Lübbertberg, no large-scale quarrying can be recommended. The rocks are often brittle and highly siliceous and are usually too intensely fractured to be suitable for the extraction of large blocks. Distance to the nearest railway is another adverse factor.

V. VARIOUS LESS SIGNIFICANT MARBLE DEPOSITS

The present investigation was directed more specifically at the economically more promising marble deposits in the Territory. A number of other occurrences were also briefly inspected although, at this stage, they cannot be seriously considered for profitable dimension stone quarrying.

A. MARBLE DEPOSITS WEST AND SOUTHWEST OF REHOBOTH

West and southwest of Rehoboth notable deposits of marble and limestone are present in three different units, namely the Elim Formation, the Swakop Group and the Nama Group. Those belonging to the last are the only ones which might be of some economic value. This holds in particular for the attractively coloured marbles of the Naukluft Mountains. However, the main obstacle which will prevent profitable production is the considerable distance to the nearest railhead or harbour.

1. Marble of the Elim Formation

Several layers up to 60 m thick of greenish-grey and greyish-brown marble are developed within a succession of Precambrian quartzite, phyllite and metalava in the area to the west of Rehoboth. The marble is medium to coarse grained and generally siliceous. The better quality outcrops are found about 70 km southwest of Rehoboth on Samkubis 516 and on the eastern portion of Grauwater 341.

2. Marble of the Swakop Group

West of Rehoboth major deposits of marble are developed at two stratigraphic levels within the Swakop Group, namely in the basal and upper portions of the Hakos Subgroup.

The marble, which occurs at or near the base of the Hakos, can be found between Dagbreek 394 (about 110 km west of Rehoboth) and Nineis 246 (30 km north-northwest of Rehoboth). It attains a thickness of some 100 m and is a fine to medium-grained white or silvery-grey dolomitic rock with talc, muscovite, quartz and a little tremolite as impurities. The rock is usually intensely sheared and unsuitable for the dimension stone industry.

Farther south, on Probeer 398 and Middelplaas 415 (110 km west-southwest of Rehoboth), the basal portion of the Hakos Subgroup is also preserved in a syncline. It includes some 280 m of fine-grained slightly banded marble which exhibits a variety of colours ranging from light grey with shades of pink, green, yellow and violet, to more purple, red, maroon and brown. Unfortunately they are brittle, rich in impurities like talc, mica, quartz and tremolite, and intensely fractured.

Higher up in the Hakos succession grey to dark-brown and black calcitic marble with many impurities such as mica, quartz and carbonaceous matter is developed. The main occurrence of this type, which does not appear to be of any economic value, is between Kos 28 and Natas 220, some 80 to 90 km west of Rehoboth.

3. Limestone and Marble of the Nama Group

Calcareous rocks occur frequently in the lower Nama succession, namely in the Kuibis and Schwarzrand Formations.

(a) Deposits between Vingerbreek Oos 473 and Garies Oos 489

The farms Vingerbreek Oos 473 and Garies Oos 489 lie respectively 80 km south and 85 km south-southwest of Rehoboth. Large quantities of black, red, brown, pink and grey calcareous rocks showing different stages of recrystallisation are developed between these two localities. The rock is unsuitable for use as dimension stone due to insufficient recrystallisation (which will affect the ability of the rock to take a polish), the presence of impurities, and strong fracturing.

(b) Deposits in the Naukluft Mountains

In the Naukluft Mountains some 100 to 120 km southwest of Rehoboth the Nama Group comprises a great variety of rocks including dolomite, limestone and occasionally marble. These rocks appear as several nappe units which, under the influence of gravity, have moved down one side of a basin, becoming folded in the process (Korn and Martin, 1959). While the dolomite is almost everywhere intensely sheared and brecciated, certain layers of pure limestone have undergone plastic deformation during which they became recrystallised. Among these occurrence of limestone and marble there are deposits suitable for quarrying as dimension stone.

On Büllsport 172, about 4 km northwest of the homestead and some 500 m west of the main road to Abbabis 3, a succession of pink, beige, reddishbrown, light-green and violet to dove-grey, very fine-grained pure marble is exposed. The deposit, which extends into the mountains for several kilometres, is also found east of the road on the slope of a hill called Bullenkopf. The rock is strongly deformed and exhibits a well-developed platy structure. A series of completely flat marble slabs arranged parallel to each other and often separated by a thin coating of slate is apparent. The slabs, up to 2 m^2 in size, may attain varying thicknesses; most of them can be split down to a width of 3 cm. The platy structure of the rock adds to its value, as cutting is unnecessary and the recovered slabs need only to be polished.

Immediately north of Büllsport 172 two other deposits of reddish to violet-grey banded marble are found on Tsabisis 340. One is situated some 500 m east of the homestead and the other about 10 km farther east. The rock is fine grained and massive and displays a striking pattern due to intense folding. As the fracturing is moderate, blocks of marketable size should be obtainable. A conglomeratic limestone which is locally recrystallised to a fine-grained bluish marble is present over a large portion of the Naukluft area. It consists mainly of black limestone and yellow and white dolomite. The rock is often thinned to such an extent that the pebbles are rolled to mere streaks. A layer of striped bluish limestone 2 to 3 m thick is exposed north of Tsabisis 340 on Garies 488, about 8 to 10 km northwest and southwest of the farm house.

B. MARBLE DEPOSITS IN THE OTJIWARONGO-OUTJO-OTAVI AREA

In the Otjiwarongo-Outjo-Otavi area extensive deposits of limestone and dolomite as well as some marble occur. These calcareous rocks all belong to the coeval Swakop and Otavi Groups. While the highly metamorphic marble (Swakop Group) in the vicinity of Otjiwarongo was deposited under eugeosynclinal conditions, the limestone and dolomite of the Outjo-Otavi area form part of the miogeosynclinal Otavi Group, the border-line between the two units lying about 10 to 15 km south of Outjo and trending in a northeasterly direction towards Otavi.

None of the marbles encountered in the area are deemed suitable for decorative purposes. They are generally too coarse grained, the colours are rather dull and impurities in the rock are quite common.

1. Limestone and Dolomite at Outjo

The limestone and dolomite which occur around Outjo are regarded as forming part of the lower Otavi Group. Most common within this sequence are grey banded platy and massive dolomites containing layers and lenses of chert. The rocks are generally fine grained and brittle; in places, however, layers of tough and crystalline marble may occur. Southeast of Outjo an increase in metamorphic grade results in an increase in crystallinity and grain size of the carbonate rocks. Grey and grey banded varieties have been quarried here and used as road-metal.

2. Marble Deposits Northwest of Otjiwarongo

Three major ranges of marble protrude above the landscape in the area to the north of Otjiwarongo. The rocks, which belong to the Swakop Group, strike in a northeasterly direction and dip steeply towards the southeast.

From the northwest to the southeast an increase in the grade of metamorphism can be observed. Consequently the more highly metamorphosed marbles are found immediately north of Otjiwarongo on Cleveland 17, Honigberg 300 and Wagner l4. They are coarse-grained light-grey to white rocks with graphite plates up to 8 mm across, which are either disseminated throughout the rock mass or concentrated in layers. This marble has been quarried on Cleveland 17 and used as road-metal, but it is regarded as unsuitable for decorative purposes.

The most important marble deposit of the area occurs a few kilometres farther to the northwest on Omatjenne 20 and Buffelhoek 342. It forms a prominent mountain which can be followed in a northeasterly direction to Jägerhof 11. The rock is coarsely crystalline, tough and contains small amounts of graphite. It generally exhibits a coarse banding caused by an alternation of grey, light-grey and white layers 10 to 50 cm in thickness. On Omatjenne 20, about 1 km northeast of the tarred road to Outjo, a coarse-grained medium-grey and light-grey to white marble has been quarried for road-metal. Because of its coarseness, the presence of impurities (mainly graphite) and its dull colour it is not considered suitable for decorative purposes. Another marble occurrence, which is at present being quarried for road-metal, is situated about halfway between Otjiwarongo and Outjo on Naribis 166. It is a crystalline, medium-grained grey and slightly banded rock which in places includes a certain amount of pyrite. In the quarry prominent jointing is exposed, which renders the deposit unsuitable for the recovery of large blocks.

C. MARBLE DEPOSITS IN THE MALTAHÖHE AND LÜDERITZ DISTRICTS

Calcareous rocks of the Kuibis and Schwarzrand Formations (Nama Group) occur abundantly in the Zaris Mountains (west of Maltahöhe), the Huib Plateau (southeast of Aus) and the Huns Mountains (west of the Fish River Canyon). Locally the limestones may be recrystallised, but usually these marble bodies are of limited extent. Although they display a variety of attractive colours, they generally occur in rugged country with few or no transport facilities.

Some years ago one such deposit was worked on a small scale on Swartkloofberg 95, about 160 km southeast of Lüderitz, for the manufacture of small ornaments.

DIE MARMERAFSETTINGS VAN SUIDWES-AFRIKA

OPSOMMING IN AFRIKAANS

INLEIDING

In Suidwes-Afrika kom aansienlike marmerafsettings voor in ‘n hele aantal geologiese eenhede waarvan die Groepe Swakop en Nama die belangrikste is.

In hierdie verslag word die term “marmer” beperk tot metamorfe gesteentes wat bestaan uit gerekristalliseerde kalsiet enjofdolomiet. In die boubedryf egter, word alle kalkhoudende gesteentes wat gepoleer kan word as marmer geklassifiseer. Hierdie gesteentes sluit onder meer aragoniet en travertyn in en selfs ook sekere serpentyngesteentes wat baie min kalsium en magnesiumkarbonaat bevat.

Suiwer marmer het ‘n wit kleur. Die groot verskeidenheid kleure en patrone wat gewoonlik in die meeste voorkomste van marmer aangetref word, word veroorsaak deur die aanwesigheid van klein hoeveelhede onsuiwerhede soos byvoorbeeld ysteroksied, koolstof en serpentyn. Wanneer dié onsuiwerhede gedissemineerd in die gesteente voorkom, word eenvormige kleure aantref; as dit egter in bande voorkom, kan ‘n gestreepte variëteit verwag word. Voorts kan plooiing en breksiëring tot ’n nog groter verskeidenheid van patrone aanleiding gee. Die voorkoms van die gesteente bepaal in ’n groot mate die uiteindelike aanwending daarvan.

Wanneer ‘n marmerafsetting ge-evalueer word, is kennis van die tekstuur, samestelling en sterkte van die gesteente en die geologiese struktuur van die afsetting essensieël. ‘n Fynkorrelrige marmer is gewoonlik duursamer as ‘n grofkorrelrige variëteit. Dit wil ook voorkom asof ‘n marmer wat òf uit suiwer kalsiet òf uit suiwer dolomiet bestaan, sterker is as ‘n gesteente wat uit ‘n mengsel van dié twee minerale saamgestel is. Wat struktuur betref, is die genaatheid van ‘n afsetting van die grootste belang. Onreëlmatige en diggespasieerde nate maak ‘n afsetting waardeloos terwyl nate wat reëlmatig (en reghoekig) gespasieer is ‘n groot bate kan wees by die ontginning van marmerblokke, mits hulle op redelike afstande, sê een meter of meer, uitmekaar voorkom. Blokke van sowat 1 m^3 word gewoonlik beskou as ‘n hanteerbare en bemarkbare grootte vir die sierklipbedryf.

‘n Volledige geologiese evaluasie van die werklike omvang van ‘n marmervoorkoms, variasies in kleur en patroon, plooiing en naatvorming in die gesteente en die diepte van verwering kan slegs aan die hand van kernboorwerk gedoen word.

MARMERVOORKOMSTE IN DISTRIK KARIBIB

Die omvangryke marmerafsettings in die omgewing van Karibib was reeds aan die begin van die eeu bekend en ‘n grootskaalse poging is in die jare wat die Eerste Wêreldoorlog onmiddellik voorafgegaan het van stapel gestuur om maatklip in hierdie distrik te ontgin. Die belangrikste marmergroewe wat uit hierdie tyd dateer, word gevind op Navachab 58 (wit marmer), by Dernburgheuwel op die plaas Karibib 54 (ligrooi “Esserando”-marmer; wit-, grys- en rooibruingestreepte en geplooide “Kudu”-marmer; lig tot donkergrysgestreepte en geplooide “Herero”-marmer; “Rote Brekzie” en “Damara”-instortingsbreksie) en by Capraheuwel, ook op laasgenoemde plaas, waar wit- en grysgestreepte en geplooide “Zebra II-marmer voorkom (voubl. 1). Meer onlangs is nog twee groterige klipgroewe begin in wit marmer, naamlik op Mon Repos (fig. 5) en by die “Dorpsgroef” net suid van Karibib (fig. 4).

Daar word tans (1974) geen maatklip in enigeen van bogenoemde groewe afgebou nie. Marmorwerke Karibib gebruik Marmer slegs op ‘n klein skaal vir die vervaardiging van grafstene, tafelblaaie en ‘n verskeidenheid ornamente. Die Marmer word verkry van los blokke in die bestaande groewe, maar ook vanaf enkele ander lokaliteite in die omgewing waar die firma sporadies en op ‘n klein skaal Marmer afbou. ‘n Tweede onderneming op Karibib produseer marmergruis vir die vervaardiging van terrasso en marmerrofkas.

Voublaaie 1 en 2 en figure 3 tot 5 toon die gebied wat tydens die huidige ondersoek gekarteer is. ‘n Aantal belangriker voorkomste word verder ook op ‘n groter skaal aangedui (voubl. 3 en 4 en fig. 6 tot 8). Daar is altesaam 14 kernboorgate gemaak om die geaardheid van enkele afsettings tot ‘n diepte van sowat 20 m vanaf die oppervlak te ondersoek.

Die Marmer kom voor in die Formasie Karibib van die Groep Swakop en bereik ‘n dikte van tot 500 m. Grys en donkergrysgestreepte Marmer is die oorwegende variëteite, maar groot hoeveelhede grys en liggrys, wit, rooierige witgevlamde grys tot swart Marmer (intraformasiebreksie) is ook aanwesig (fig. 2). Kleiner afsettings van groen, swart en bruinerige variëteite, asook instortingsbreksies kom plek-plek voor.

Die marmers is deurgaans dolomities en varieer in korrelgrootte van fyn tot grof, hoewel die meeste as middelkorrelrig beskryf sou kon word. Baie van die marmers, veral dié oos van Karibib, bevat aansienlike hoeveelhede onsuiwerhede soos chert en kalksilikate en sal waardeloos wees vir die maatklipbedryf. Daar is ook gevind dat vanweë die grootskaalse verplooiing wat die Marmer ondergaan het, diggespasieerde nate redelik algemeen ontwikkel is. Heelparty andersins belowende afsettings is daardeur nadelig getref.

Sover dit verwering aangaan, wil dit voorkom asof sommige wit en ligkleurige afsettings besonder vatbaar was vir die vorming van onreêlmatige oplossingsholtes. Met langdurige blootstelling neig baie van die wit marmers om suikeragtig te word (a.g.v. verswakking van die tussenkorrelbinding), terwyl gestreepte soorte dikwels parallel met die gestreeptheid splits. In die meeste gevalle egter het die natuurlike verwydering van verweerde rots goed tred gehou met die verweringsprosesse sodat groot en redelike vars dagsome betreklik algemeen voorkom.

Boorwerk het aangetoon dat ‘n afsetting wat op die oppervlak sterk genaat of aansienlik verweer is, gewoonlik nie beduidend verbeter binne die eerste 20 m vanaf die oppervlak nie. Ekonomiese ontginning van marmerblokke sal dus beperk wees tot afsettings wat reeds aan die oppervlak van ‘n goeie kwaliteit is.

Vier-en-twintig monsters, verkry van die kernboorgate, is deur die Nasionale Bounavorsingsinstituut van die WNNR in Pretoria ondersoek. Daar is bevind dat die marmermonsters dig is met ‘n baie lae waterabsorpsievermoë en dat hulle druksterkte relatief hoog is. Nietemin laat die Manier waarop party marmermonsters onder hoë druk “versuiker”, die vraag ontstaan of die gebruik daarvan vir buiteversiering wenslik is.

Die gevolgtrekking word gemaak dat sommige van die Karibibmarmers wel geskik sal wees vir die maatklipbedryf. Dit sluit onder andere in die gevlamde marmers wat oor ‘n groot gebied in bande van 3 tot 15 m wyd voorkom, die wit Marmer van Mon Repos en omgewing, ‘n wit marmerbreksie wat by Dernburgheuwel voorkom en waarskynlik ook die ligrooi “Esserando”-marmer van dieselfde heuwel. Dit sal nietemin in die laaste instansie ekonomiese oorwegings soos ‘n bestendige mark, ontwikkelingskoste, aanwending van afvalklip en spoor- en arbeidskoste wees wat sal bepaal of die marmer van Karibib winsgewend ontgin kan word al dan nie.

MARMERVOORKOMSTE IN DIE SWAKOPMUND-WALVISBAAIGEBIED

Marmer wat met die Formasie Karibib van die Groep Swakop gekorreleer word, kom hoofsaaklik in twee gebiede voor, naamlik vanaf Swakopmund ooswaarts tot by Rössingberg, en in 'n lang rug wat vanaf Swartbankberg noord-noordooswaarts tot by die Hamiltonberge strek (fig. 9 en 10). Hoewel hierdie voorkomste reeds vroeg in die eeu aandag geniet het, is nog net sporadiese en kleinskaalse pogings aangewend om marmer vir maatklipdoeleindes af te bou. Die bekendste daarvan is die geel-groen serpentynhoudende marmer wat deur Marmorwerke Karibib naby Nonidas ontgin is.

Wit, grys, grys gestreepte, bruinerige en groen marmer, asook 'n gevlamde wit en grys soort, kom in dié gebied voor. Die dikte van die marmereenheid varieer aansienlik, maar kan benaderd op 500 meter gestel word. As gevolg van 'n hoër graad van metamorfose is die Swakopmund-Walvisbaai-marmers deurgaans growwer as dié wat by Karibib aangetref word, terwyl nate ook nie so intens ontwikkel is nie.

Behalwe dat die marmer meestal grofkorrelrig is, is die meeste soorte ook dikwels gekontamineer deur chert en kalksilikate, terwyl die voorkoms daarvan ook nie besonder aantreklik is nie. 'n Uitsondering is die geelgroen serpentynhoudende marmer oos van Swakopmund en, in 'n mindere mate, die gevlamde marmer wat by Swartbankberg aangetref word. Eersgenoemde kom voor in 'n verskeidenheid van skakerings en patrone en dit poleer goed. Die groot reserwes voorhande en die nabyheid aan die Walvisbaaihawe maak die groen marmer 'n belowende proposisie sover dit die ontginning van maatklip aanbetref.

Die besonder grofkristallyne wit kalsietmarmer direk oos van Swakopmund sal geskik wees as 'n grondstof vir die produksie van sement.

MARMERAFSETTINGS SUID VAN WINDHOEK

Suid en suidoos van Windhoek kom marmerbande wat in dikte vanaf enkele meter tot 'n maksimum van sowat 120 m varieer op drie stratigrafiese horisonte in die Groep Swakop voor (fig. 11).

Die marmer is grys gestreep, wit, grys en rooierig tot bruin en is oorwegend middel- tot grofkorrelrig. Op baie plekke is die marmer onbruikbaar vir maatklipdoeleindes as gevolg van intense genaatheid, skuifskeursones en/of onsuiwerhede SOOS silika, talk en mika wat daarin voorkom.

'n Redelike goeie kwaliteit suiwer wit middelkorrelrige marmer kom voor op die plaas Gocheganas 26, sowat 5 km noordoos van Leutweinsylyn (fig. 11 en 12). Hierdie afsetting word tans gewerk vir die produksie van terrasso en marmerrofkas, maar dit behoort ook geskik te wees vir blokherwinning.

Die enigste ander afsetting in die Windhoekomgewing wat vermelding verdien, is dié by Lübbertberg, sowat 80 km suidoos van die stad (fig. 13). Hoewel groot hoeveelhede redelik aantreklike rooskleurige, bruin, grys en wit marmer aanwesig is, is die gesteente dikwels bros, gekontamineer deur silika en meestal sterk genaat. Daarbenewens moet die relatief groot afstand na die naaste spoorlyn ook in gedagte gehou word.

ANDER MINDER BELANGRIKE MARMERVOORKOMSTE

Die huidige ondersoek was veral toegespits op die meer belowende marmerafsettings wat binne 'n redelike afstand van bestaande verbindingsweë voorkom. Daar is egter nog talle ander voorkomste in Suidwes-Afrika wat onder die huidige omstandighede waarskynlik nie ekonomies afgebou sou kon word nie.

Wes en suidwes van Rehoboth kom Marmer in die Formasie Elim, in die Groep Swakop en in die Groep Nama voor. Laasgenoemde is die belangrikste en dit is veral in die Naukluftberge, 100 tot 120 km suidwes van Rehoboth, waar aantreklike fynkorrelrige ligroos tot salmkleurige, rooibruin, liggroen en pers tot duifgrys Marmer daarin aangetref word.

Noordwes van Otjiwarongo kom ook aansienlike hoeveelhede Marmer in die Groep Swakop voor. Die gesteente is egter te grofkristallyn en gekontamineer deur onsuiwerhede, en te somber van kleur om geskik geag te word vir dekoratiewe doeleindes.

In die distrikte Maltahöhe en Lüderitz kom wydverspreide kalksteenafsettings in die Groep Nama voor. Plek-plek is hierdie kalksteen gerekristalliseer tot Marmer. Aangesien laasgenoemde slegs sporadies ontwikkel is en ver van bestaande verbindingsweë lê, is dit nie verder ondersoek nie.

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APPENDIX

BUILDINGS IN WHICH MARBLE FROM SOUTH WEST AFRICA WAS USED

City or town	Building	Variety of marble*
Johannesburg	Post Office, Jeppe Street	Mon Repos white (34)
Karibib	Post Office (gable)	Light-grey flamed ("Sander") (28), "Town Quarry" white (44)
	Municipal Office (flooring)	Nonidas green (48)
Swakopmund	Post Office (interior decoration) (Plate XX)	Nonidas green (48)
Walvis Bay	Old Mutual Building (exterior cladding)	Light-grey flamed ("Sander") (28)
Windhoek	Anna Vögler Building (boxframe display windows)	"Esserando" (19)
	Barclays Bank, Ausspannplatz (facade) (Plate XV)	Black flamed (10)
	Legislative Assembly Building (interior decoration) (Plate XXI)	Various marbles, including "Esserando" (19), "Rote Brekzie" (14), "Kudu" (18), "Zebra" (30), "Leopard" (15)
	State Hospital (interior cladding; architrave) (Plate XIII)	Dove-grey (38); light-grey flamed (28), "Leopard" (15)
	Supreme Court (architrave)	Black flamed (10)
	S.A. Reserve Bank (interior cladding, flooring)	Various marbles, including Mon Repos white (34), "Esserando" (19), Nonidas green (48)
	Carl List Haus (exterior and interior cladding) (Plate XIV)	Light-grey flamed ("Sander") (28)

*Figures in brackets refer to locality numbers used in this publication.

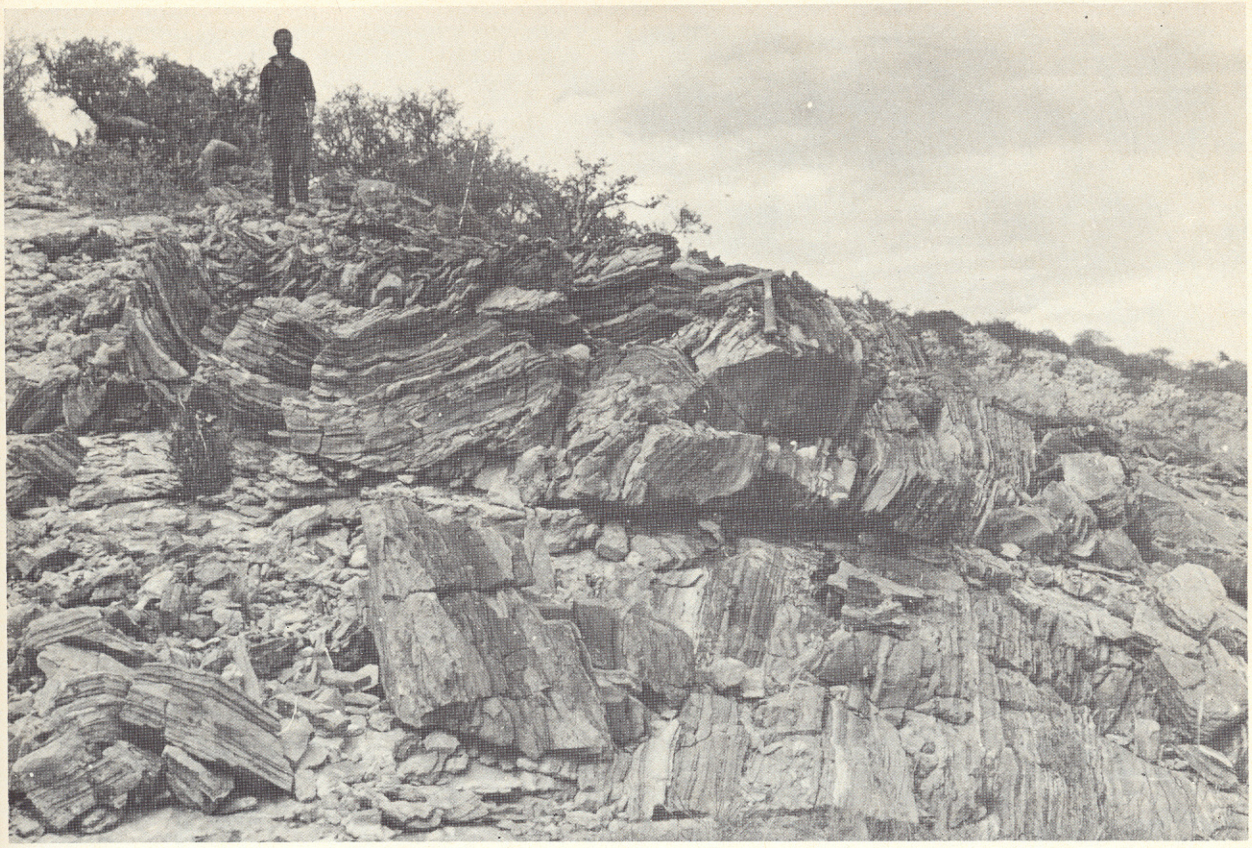

Plate I.—Third-order fold (10-m range) in marble with fourth-order folds in the core, Navachab 58.
Plaat I.—Plooi van derde orde (10-m-grootte) in marmer met plooie van vierde orde in die kern, Navachab 58.

Plate II.—Fourth-order folds in the core of a larger structure, Capra Hill (Karibib 54).
Plaat II.—Plooie van vierde orde in die kern van 'n groter struktuur, Capraheuwel (Karibib 54).

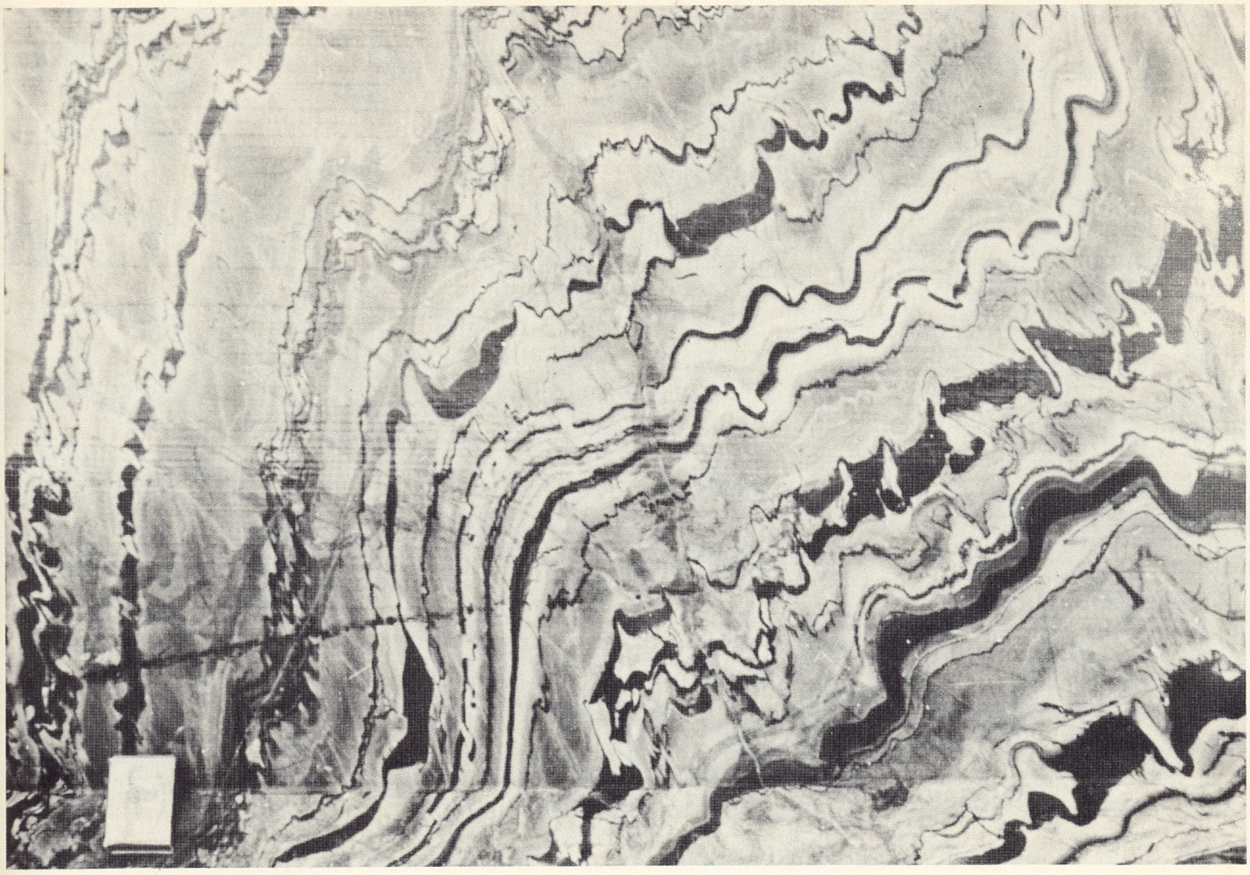

Plate III.—Parasitic folds (fourth-order) in the core of a larger structure. "Kudu" marble quarry, Karibib 54 (loc. 18).
Plaat III.—Parasitiese plooie (vierde orde) in die kern van 'n groter struktuur. "Kudu"-marmergroef, Karibib 54 (lok. 18).

Plate IV.—Drag folds in grey banded marble. "Herero" marble quarry, Karibib 54 (loc. 17).
Plaat IV.—Sleurplooie in grys gestreepte marmer. "Herero"-marmergroef, Karibib 54 (lok. 17).

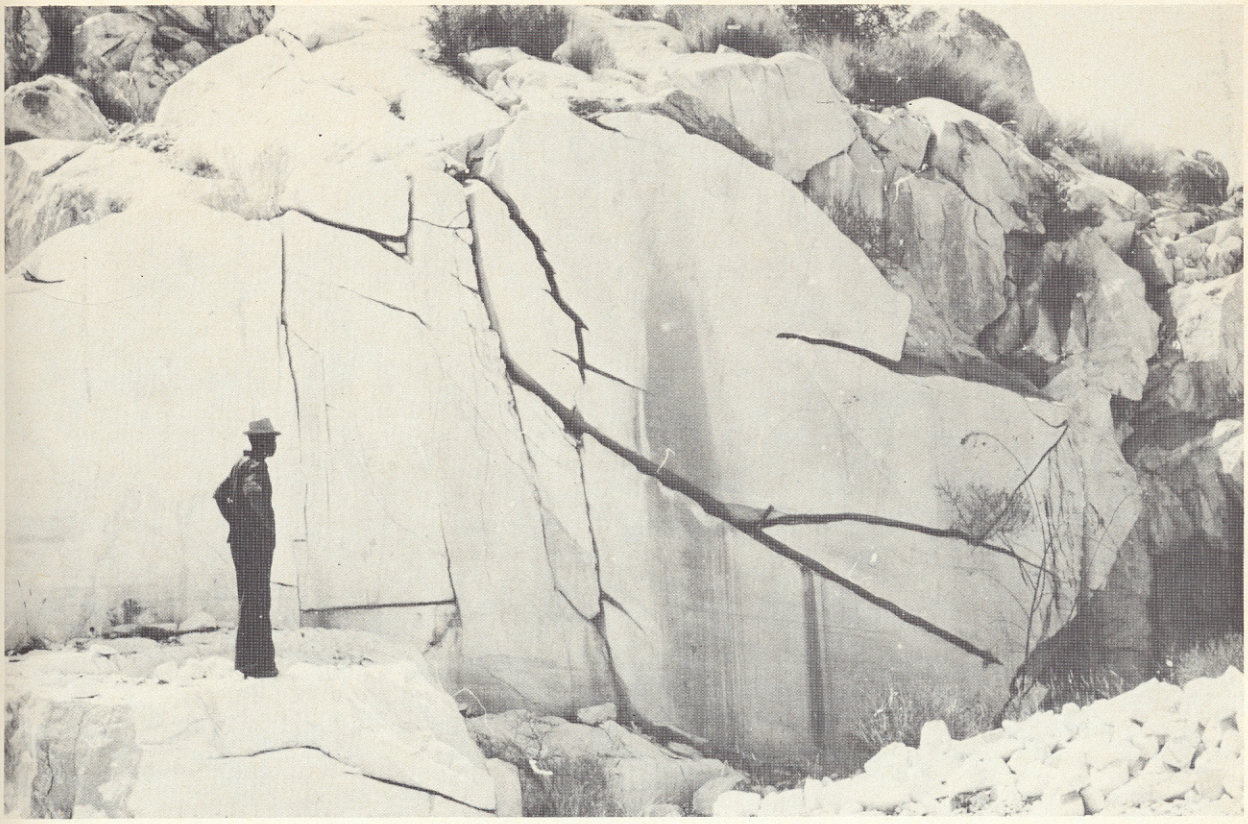

Plate V.—Joints widened to fissures (solution fissures) in white marble. "Town Quarry", Karibib 57 (loc. 44).
Plaat V.—Nate wat tot splete (oplossingsplete) in wit marmer verbreed het. "Dorpsgroef", Karibib 57 (lok. 44).

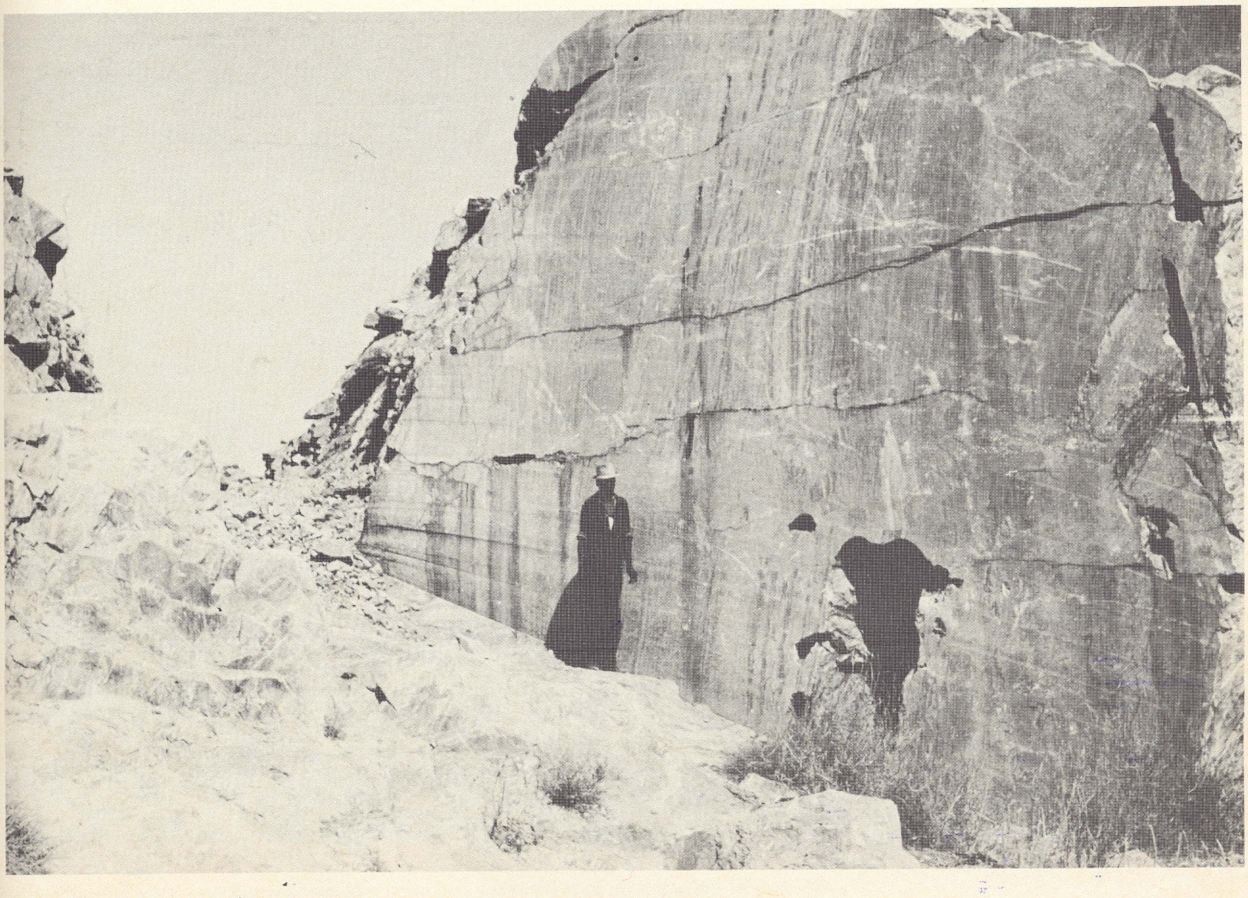

Plate VI.—Horizontal joints and solution cavities, "Kudu" marble quarry, Karibib 54 (loc. 18).
Plaat VI.—Horisontale nate en oplossingsholtes, "Kudu"-marmergroef, Karibib 54 (lok. 18).

Plate VII.—Irregular joints near surface due to fluctuations in temperature. "Kudu" marble quarry, Karibib 54 (loc. 18).
Plaat VII.—Onreëlmatige nate naby oppervlak te wyte aan temperatuurskommelinge. "Kudu"-marmergroef, Karibib 54 (lok. 18).

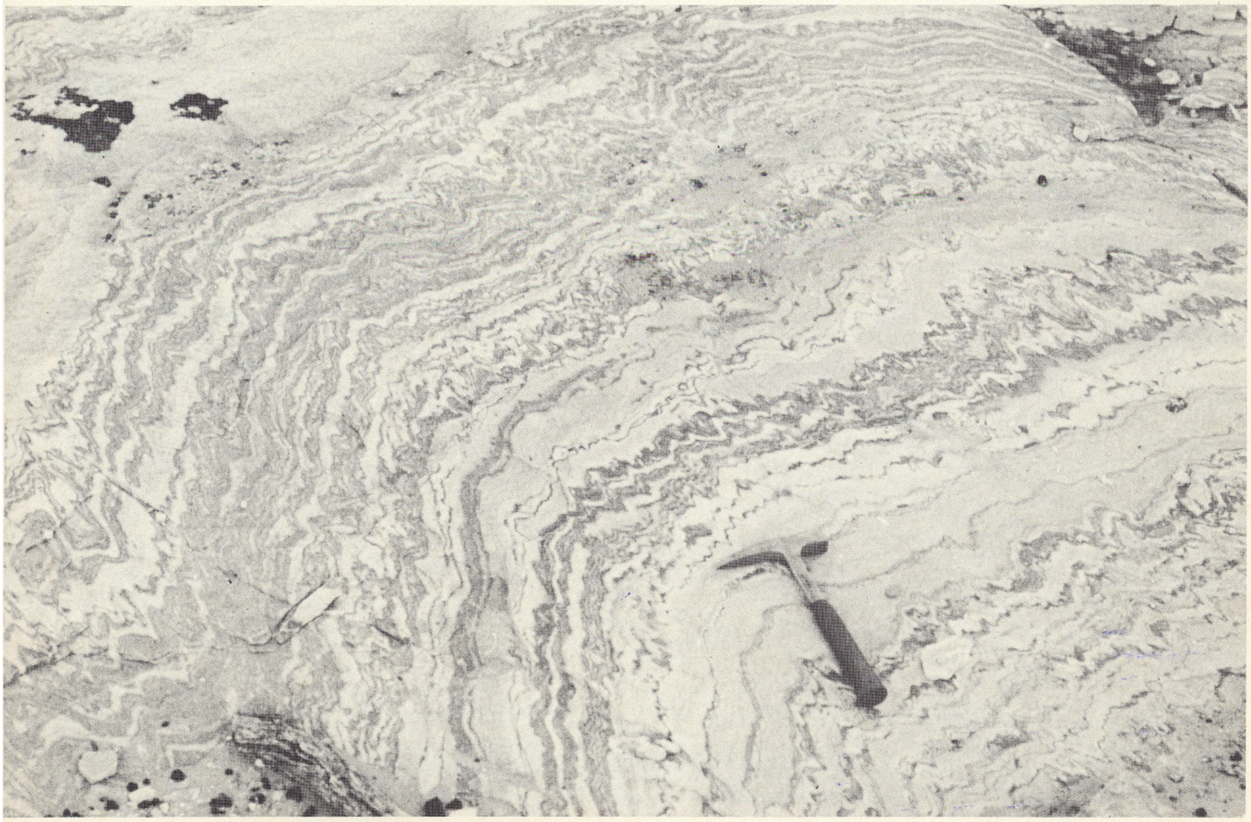

Plate VIII.—"Zebra" marble exposed in a river bed west of Capra Hill, Karibib 54 (loc. 29).
Plaat VIII.—"Zebra"-marmer, wat blootgestel is in 'n rivierloop wes van Capraheuwel, Karibib 54 (lok. 29).

Plate IX.—Various marbles from the Karibib District (see text for details): (1) "Damara", (2) "Rote Brekzie", (3) dark "Esserando", (4) light "Esserando", (5) "Kudu", (6) "Herero", (7) Grey banded, (8) "Zebra". The figures are 16 mm high. (Photographs by the courtesy of the State Museum, Windhoek.)

Plaat IX.—Verskeie marmersoorte afkomstig van die distrik Karibib (raadpleeg teks vir besonderhede): (1) "Damara", (2) "Rote Brekzie", (3) donker "Esserando", (4) ligte "Esserando", (5) "Kudu", (6) "Herero", (7) Grys gestreepte, (8) "Zebra". Die syfers is 16 mm hoog. (Foto met die goedgunstige toestemming van die Staatsmuseum, Windhoek.)

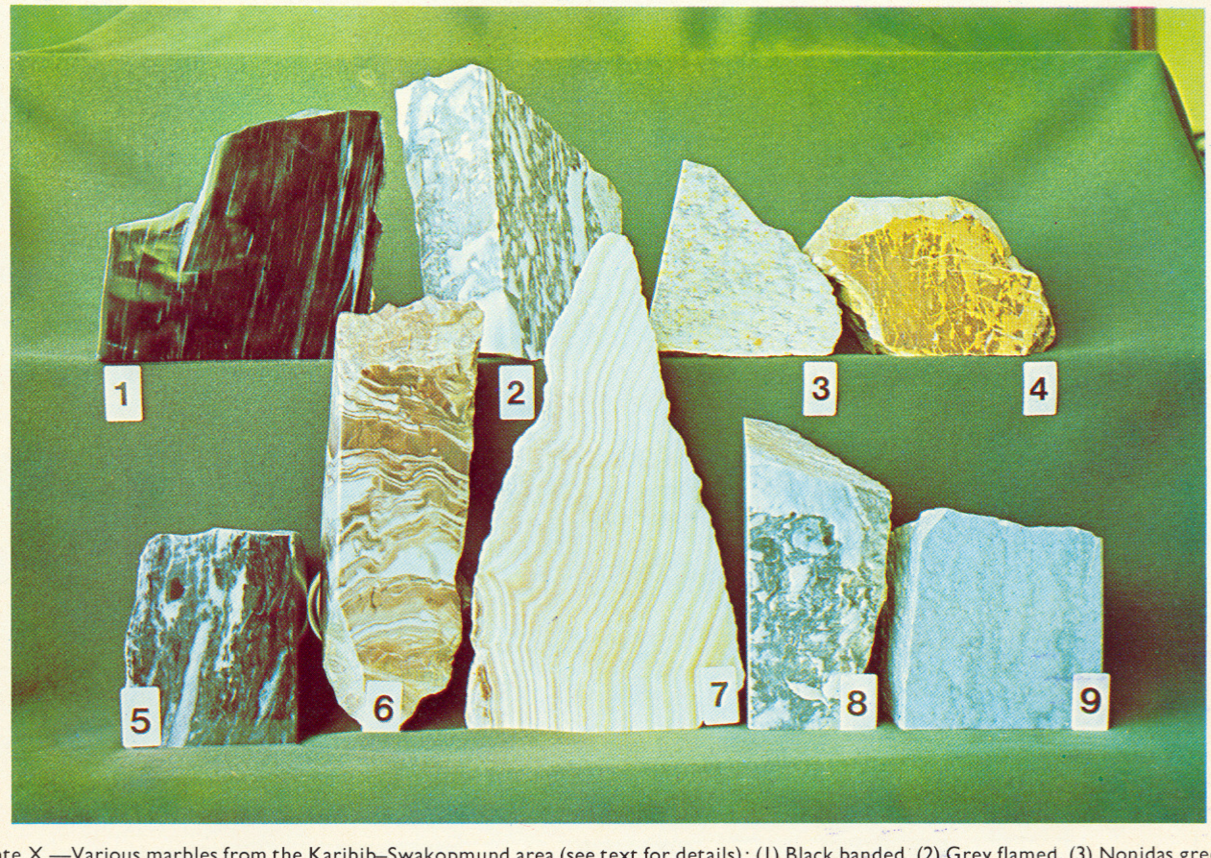

Plate X.—Various marbles from the Karibib–Swakopmund area (see text for details): (1) Black banded, (2) Grey flamed, (3) Nonidas green, (4) "Ewinde", (5) Black flamed, (6) "Antilope", (7) Aragonite, (8) "Leopard", (9) Dove-grey. The figures are 16 mm high (Photograph by the courtesy of the State Museum, Windhoek.)

Plaat X.—Verskeie marmersoorte afkomstig van die Karibib–Swakopmundgebied (raadpleeg teks vir besonderhede): (1) Swart gestreepte, (2) Grys gevlamde, (3) Nonidas-groen, (4) "Ewinde", (5) Swart gevlamde, (6) "Antilope", (7) Aragonite, (8) "Leopard", (9) Duifgrys. Die syfers is 16 mm hoog. (Foto met die goedgunstige toestemming van die Staatsmuseum, Windhoek.)

Plate XI.—Weathered surface of flamed marble consisting of white fragments in white matrix (loc. 31, fold. 1).
Plaat XI.—Verweerde oppervlak van gevlamde marmer wat uit wit brokstukke in 'n wit grondmassa bestaan (lok. 31, voubl. 1).

Plate XII.—Flamed marble with tectonically deformed fragments (loc. 20, fold. 1).
Plaat XII.—Gevlamde marmer met tektonies-vervormde fragmente (lok. 20, voubl. 1).

Plate XIII.—Dove-grey marble with irregular streaks, used for interior decoration of the State Hospital, Windhoek (loc. 38, fold. 2).

Plaat XIII.—Duifgrys marmer met onreelmatige strepe soos gebruik vir binneversiering van die Staatshospitaal, Windhoek (lok. 38, voubl. 2).

Plate XIV.—Exterior cladding of Carl List Haus, Windhoek. Grey flamed marble from locality 28 (fold. 1).

Plaat XIV.—Buiteversiering van Carl List Haus, Windhoek. Grys gevlamde marmer van lokaliteit 28 (voubl. 1).

Plate XV.—Facade of Barclays Bank (Ausspannplatz Branch), Windhoek. Black flamed marble from locality 10 (fold. 1).

Plaat XV.—Fasade van Barclays Bank (Tak Ausspannplatz), Windhoek. Swart gevlamde marmer van lokaliteit 10 (voubl. 1).

Plate XVI.—The main "Esserando" marble quarry on Dernburg Hill (Karibib 54), looking west.
Plaat XVI.—Die vernaamste "Esserando"-marmergroef by Dernburgheuwel (Karibib 54), wesaansig.

Plate XVII.—
A block of "Kudu" marble quarried before World War I. "Kudu" marble quarry, Dernburg Hill (Karibib 54).

Plaat XVII.—
"Kudu"-marmerblok wat van voor die Eerste Wereldoorlog dateer. "Kudu"-marmergroef, Dernburgheuwel (Karibib 54).

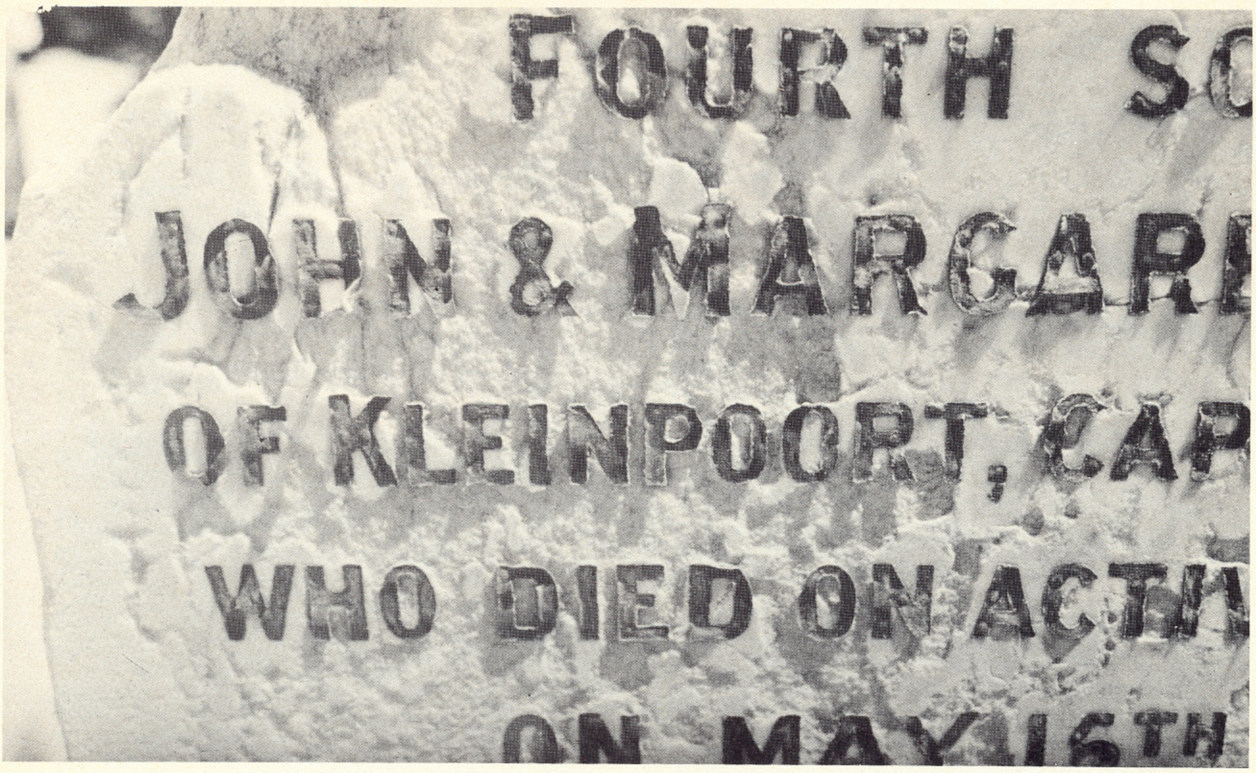

Plate XVIII.—"Sugaring" of 60-year old tombstone at Swakopmund cemetery; white Italian marble. (Photo: P. O. Petzold.)
Plaat XVIII.—"Versuikering" van 'n 60-jaar-oue grafsteen in die Swakopmundbegraafplaas; wit Italiaanse marmer. (Foto: P. O. Petzold.)

Plate XIX.—Tombstone manufactured from Karibib marble. Note discoloration, especially along cracks, due to weathering of impurities; otherwise the marble is still sound. Old cemetery, Karibib.

Plaat XIX.—Grafsteen vervaardig van Karibib-marmer. Let op die verkleuring, veral langs krakies, as gevolg van die verwering van onsuiwerhede; andersins is die marmer in 'n goeie toestand. Ou begraafplaas Karibib.

Plate XX.—Interior decoration of the Swakopmund Post Office; Nonidas green marble.
Plaat XX.—Binneversiering van die poskantoor in Swakopmund; Nonidas-groen marmer.

Plate XXI.—Various marbles from South-West Africa used for the interior decoration of the Legislative Assembly Building in Windhoek.

Plaat XXI.—Verskeie marmersoorte van Suidwes-Afrika soos gebruik vir die binneversiering van die Wetgewende Vergaderinggebou in Windhoek.