DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

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LITHOLOGICAL FACTORS INFLUENCING THE QUALITY OF GAMBIER LIMESTONE AS A BUILDING MATERIAL

GEOLOGICAL SURVEY

by

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ABSTRACT

The Marte area, 10 km west of Mount Gambier is the largest producer of building limestone in Australia. Massive calcarenite of Gambier Limestone of late Eocene to early Miocene age has been extensively modified by subsequent groundwater movement resulting in a range of lithologies with varying suitability for use as building stone.

The most coherent stone has a recognisable open fabric, a thin coating of crystalline dolomite cement, and little or no powdery lime. It results from minimal corrosion of the original bioclastic framework and is 'typical' Marte calcarenite.

Less coherent stone (e.g. Pareen stone) is fine-grained and matrix rich with few relict fossil fragments. Coherence has been diminished by substantial corrosion of the framework and deposition of an amorphous to poorly crystalline carbonate of varied composition. Although often very white, the matrix tends to be chalky and friable.

INTRODUCTION

Currently, Gambier Limestone yields more building limestone than any other stratigraphic unit in Australia with an annual ashlar output of about 20 000 tonnes per year. In addition, Gambier Limestone is an important source of glass-grade limestone, whiting and agricultural lime as well as a cheap local source of road rubble. The stone has been used since colonisation; the first pastoralists in the Mount Gambier-Mount Schank area cut limestone blocks in 1842-1844, and a convent built of the stone in 1856 was demolished in 1985.

As part of the investigation by Mineral Resources Branch of the building stones of South Australia, limestone quarries near Mount Gambier were mapped from 27 February to 7 March 1985 by D.J. Flint assisted by M.W. Flintoft (Field Assistant, Mineral Resources Branch). Aerial photography flown on 3 March 1982 was used by Photec Air Surveys Pty. Ltd. to compile a 1:5 000 base plan of quarries at Marte in August 1984. Geological data and updated quarry outlines were plotted onto the Photec plan, which has been modified to produce a new 1:10 000 base plan. Thirty-three representative samples (7022 RS 121-153) were selected for petrographic examination by M.G. Farrand (Senior Geologist, Regional Geology Branch) and for chemical analysis by Australian Mineral Development Laboratories (AMDEL). Petrographic examination was used to investigate the mineralogical and petrological basis for variations in colour, grain size, texture, resistance to weathering and general suitability as a building stone. This report details the petrography. Geological investigations include a review of geology, uses, specifications and production, and are presented in Flint (1987).

Detailed material testing was carried out by AMDEL on six samples (7022 RS 160-165), each consisting of about six 660x300x100 mm ashlars, collected on 26-27 August 1985 by A.M. Pain (Principal Geologist, Extractive Materials), D.A. Young (Senior Technical Officer) and D.J. Flint. Samples were collected to provide a geographic spread and range of typical quarry products, but not all operating quarries were sampled. Laboratory results are presented in Spry (1986) and reviewed in Flint et al. (1987).

Subsequent to these investigations, a sample of Gambier Limestone was taken by Ted Houston (then Consultant, Environmental Services Section, AMDEL) from the Supreme Court Building, Victoria Square, Adelaide as part of AMDEL's investigations into condition of stonework in that building. Dolomitised Gambier Limestone was used in the Supreme Court building for carved details such as capitals and dentil courses. Petrographic examination of this sample by M.G. Farrand is included in this report and compared with typical, calcitic Gambier Limestone.

PETROGRAPHY

Most samples are from Marte; all sample and quarry locations are shown on Figures 1 & 2.

Thin sections were prepared by impregnation with epoxy resin and treated by alizarin red dye to show relationships between calcite and dolomite. To aid petrographic interpretation, four fine-grained samples (7022 RS 125, 128, 134 and 136) were examined by AMDEL using X-ray diffraction, results showed that the apparent marly facies contained no clay but considerable fine-grained calcite (Appendix A).

Specimen 7022 RS121, TS C44837

Locality

Kain & Shelton Quarry; from old block-mining face 4.2 m high.

Hand Specimen

Medium grained, highly porous, bioclastic limestone or calcarenite, creamy white when wet but dries to off-white. It is coherent enough to retain a flat-sided shape when sawn, despite minor friability on cut surfaces. Framework is composed of bioclastic fragments, mainly of reticulate bryozoa, bonded by micrite at the points of contact. The micrite coating on fragments is not abundant enough to fill the spaces within or between them. Micrite tends to have a yellowish tint in comparison with the skeletal material.

Thin Section

Two types of organic detritus are abundant, both consist of highly porous forms, the most abundant are bryozoal but foraminifera with empty chambers are common. Organic remains are deeply stained with alizarin red dye and are assumed to be calcite. Porosity is very high.

Skeletal fragments are coated with fine grained carbonate which has not stained and is therefore not calcite, a slight yellowish tint suggests an ankeritic composition. Micrite forms individual, very fine grained crystals, usually with long axes perpendicular to the surface they coat, as well as patches of less perfect crystallinity. Some of the open meshes of the bryozoan fragments and foraminiferal chambers are filled, or partially filled, with micritic carbonate.

Some patchy, poorly crystalline interstitial carbonate is stained by the alizarin red dye and is thus calcite.

Some detrital calcite fragments are partially replaced by colourless ankeritic and dolomitic carbonate but this is a relatively minor effect.

Comment

The sediment is a cemented accumulation of relatively coarse grained detritus made up mainly of reticulate bryozoa and less abundant foraminiferal tests. The rather fragile organic remains have been very little fractured and only moderately recrystallised. The debris may have been shed from bryozoans in water deep enough to be below wave base with a current strong enough to wash out any fine material but weak enough to retain the delicate carbonate structures intact.

Cementation may have been accomplished almost at once by leaching and redeposition of carbonate rich in magnesium and probably iron. Some redistribution of carbonate has occurred after initial cementation and is responsible for the replacement of bioclastic detritus by patchy micrite.

Specimen 7022 RS122, TS C44838

Locality

Kain and Shelton Quarry; current workings.

Hand specimen

White, almost chalk white, calcarenite similar to RS121. Shows the same open framework in which skeletal material is slightly corroded but maintains intact its overall form. The rock is coherent and of good building quality.

Thin section

The rock is apparently more coherent than RS121. Fine patches of micrite, with or without a pinkish alizarin-red stain, are almost completely absent from the sectioned sample.

Development of a crystalline, colourless, micrite cement is strong as a coating and cement of the bioclastic debris. There are possibly somewhat more interstitial patches of crystalline calcite than in RS121.

Comment

Relatively coarse grain size and highly porous structure appear to be factors diagnostic of good building stone. The presence of crystalline micrite as a cement is also probably essential for a coherent building stone. Depositional conditions for RS121 and 122, appear to have been similar. The absence of fine detritus is possibly due to moderately energetic current actually during deposition but may be the result of post depositional redistribution of carbonate.

Specimen 7022 RS123, TS C44839

Locality

Kain and Shelton Quarry; current workings.

Selected to represent the darkest, creamy yellow colour available in ashlars, which are popular in Victoria but not in the Mount Gambier area. Overlying Gambier Limestone has been stained yellow, cream and orange-red by downward leaching of iron hydroxides and clay minerals from the dark red topsoil.

Hand specimen

The rock differs in several respects from samples RS121 and 122. It is yellow in colour even when dry and is less well-sorted. The fine detritus and the cement are patchily distributed so that porosity is varied and the rock is friable in places.

Thin section

The somewhat higher proportion of finely divided skeletal material is confirmed but in contrast some detritus is coarser than in the two specimens above. The combination of this factor and a patchy cement produces large areas of matrix which contrast with the more uniformly porous specimens RS121 and 122.

All but a few clasts are coated with a yellow, non-staining carbonate, probably ankerite. The holes in fenestrate bryozoa, and the foraminifera chambers are frequently filled with micrite whereas in the other specimens the micrite tends to be a thin coating. The greater friability noted in hand specimen is probably the result of thin, or poorly interlocking, cement coatings but this is not obvious in thin section.

A little interstitial calcite is present but more well-crystallised calcite occurs in skeletal fragments, spines and plates of echinoderms.

Comment

The sediment is less well sorted and less evenly cemented than RS121 and 122 but was probably deposited in a similar environment, a field of bryozoa growing below the wave base. Patches of fine grained matrix are probably the product of post depositional processes.

The yellow colour appears to be the result of iron concentration considerably post dating deposition.

Specimen 7022 RS124, TS C44840

Locality

Bruhn Quarry; extreme southeastern end of main ridge; from southern face of current workings.

Hand specimen

Intermediate in colour and texture between RS123 on one hand and RS121 and 122 on the other. The overall colour is creamy white but bryozoan fragments tend to be chalk white while the fine matrix is similar to RS123 and is a pale greenish yellow colour. Porosity is lower than in the specimens from the central section of the ridge and friability is greater.

Thin section

Much of the rock consists of an open structure of coarse bryozoan fragments held together with a dolomitic or ankeritic cement, similar in most respects to specimens RS121 and 122. The main difference is in a higher concentration of foraminiferal tests, echinoderm fragments and interstitial calcite of indeterminate origin. Carbonate skeletal fragments have been stained brownish red by alizarin red and the fragments possibly retain a chitinous component.

The remainder of the rock is similar texturally to RS123, comprising a matrix of coarse and finer bioclastic grains in a cement of clear dolomitic or ankeritic micrite. This lithology persists over a considerable area and produces patches of low porosity in comparison to the open, highly porous structure of the coarse grained lithology.

A few fine, angular grains of quartz and very rare grains of microcline are present.

Comment

Another example of bioclastic material accumulated below the wave base in a weak current. The yellowish, fine grained carbonate is probably not of detrital origin.

Specimen 7022 RS125, TS C44841

Locality

Bruhn Quarry; from southern face of current workings.

Selected deliberately to represent material classified as 'thirds' i.e. variable texture with a fine grained, chalky and somewhat friable component dominating but with coarse-grained patches. Blocks apparently have lower cohesive strength and many have chipped corners.

Hand specimen

Chalk white, fine grained, friable and powdery calcarenite. Large areas are extremely fine grained but contain occasional coarse grained, bioclastic fragments. Variation in texture between fine grained and very fine grained imparts a somewhat nodular appearance in places but elsewhere a roughly linear variation gives the appearance of a weakly bedded texture to the rock. Friability and low overall strength have caused deterioration in the rectangular, sawn specimen, corners have broken off and faces have lost material by powdering and flaking.

RS125 was investigated by X-ray diffraction but any component other than calcite was below detection limit - about 5% (Appendix A).

Thin section

The appearance of bedding is confirmed by the presence of very irregular, sub-parallel bands stained pink by alizarin red dye. In transmitted light with low magnification these bands appear brownish and poorly translucent. With higher magnification both brownish and pinkish micrite are seen to be closely intergrown. The brownish, presumably dolomitic or ankeritic, carbonate forms a matrix for small patches of pink, presumably calcitic, carbonate. The entire material has a speckled appearance.

At low magnification it is evident that the pink patches are remnants of recognisable bioclastic fragments, and some very coarse grained fragments are almost unmodified in shape. At high magnification the pink-stained objects which can be resolved are generally not recognisably organic but, on the evidence of coarser grained fragments, are very likely to be of the same origin. It is thus reasonable to suppose that the micritic patches are the product of replacement, to varying extents, of the original bioclastic material.

Areas without the continuous micritic matrix consist of a highly porous, open framework of fragments of bryozoa and occasional foraminifera similar to the above specimens but grain size is finer. Much of the porosity relates to the original organic structures but a large proportion of cavities are clearly secondary and are also the product of solution processes. Most original calcite fragments are corroded but now have a coating of crystalline ankerite or dolomite.

Comment

Much of the original sediment has been removed by dissolution, or replaced by solution processes. There is some evidence that the original limestone was finer grained than other specimens in this suite but the major differences between those and RS125 are due to the greater extent of post depositional reactions between framework and pore solutions in the latter.

Specimen 7022 RS126, TS C44842

Locality

Bruhn Quarry.

Hand specimen

Typical of material used in larger foundation blocks rather than ashlars. Chalk white, somewhat powdery calcarenite, but is much less friable and more coherent than RS125. It is more uniform in texture and retains its cut form without corners breaking off or flat surfaces crumbling away. The framework includes a few bioclasts of very coarse grain size but for the most part appears to be relatively fine grained and generally well sorted. Porosity is relatively high.

Thin section

The sample sectioned may not be entirely representative of the stone on the scale of a building block. The rock resembles closely those areas of RS125 comprising an open framework without much micritic matrix.

Fragmented bryozoal debris makes up most of the framework with minor foraminiferal grains and moderately abundant fragments of echinoderm spines and plates.

Framework grains are cemented by thin layers of yellowish micrite. Few patches of micrite occur and these are parallel and interstitial. Most of the pores in fenestrate bryozoa are empty and much of the framework shows evidence of partial dissolution by pore solutions. Many interstitial pores are enlarged by dissolution.

Comment

Post depositional processes, particularly reactions between framework and pore solutions appear to be the major factor determining the suitability of this rock for use as a building stone.

The sediment is slightly finer grained and better sorted than more coherent samples examined eg RS121 and 122. The stone is probably stronger than both RS124 and 125.

Specimen 7022 RS127, TS C44843

Locality

Knight and Pritchard Quarry; abandoned working.

Hand specimen

Most of the sawn block consists of good quality building stone. Corners cannot be broken with the fingers. One end is friable and powdery and can be crumbled with the fingers. A weakly oriented fabric is visible at a low angle to the long faces of the block. Most bioclastic fragments are of tubular rather than reticulate bryozoa. Grain size is relatively fine but sorting is generally poor.

Thin section

The section is presumed to be cut from the more coherent part of the rock.

The dominant features are the effects of dissolution and re-precipitation. The coherence of the specimen is probably due to the crystalline rather than amorphous structure of the precipitated carbonate. While some small patches of amorphous micrite are present, the major part of the cement is crystalline, which is abundant enough to form a continuous matrix in places.

Much bioclastic debris has been reduced to highly corroded remnants and in some fragments original calcite is less abundant than recrystallised carbonate. Most clastic material is derived from bryozoa with a few spines and plates of echinoderms and very few recognisable foraminifera, possibly due to the extensive recrystallisation.

The carbonate of the cement and partial matrix is colourless and is probably dolomite without significant iron content.

Comment

The highly corroded and replaced nature of the bioclastic material has not prevented a high degree of coherence in much of the fabric. The critical factor is possibly the high crystallinity of the fine, dolomitic carbonate. A section cut from the friable part of the block would probably reveal the presence of a fine, amorphous, micritic matrix, and would suggest the rock is less suitable for use as building stone.

Specimen 7022 RS128, TS C44844

Locality

Knight and Pritchard Quarry; easternmost quarry. Current quarry but material now used only for agricultural lime; old faces indicate prior use for building stone.

Hand specimen

The sample exhibits low strength, high friability and high fine powder content. It is possible to break the material between the fingers. It is predictably high in amorphous micrite and was selected for X-ray diffraction to determine clay content. Although greenish yellow and brown material appeared to be marly, calcite was the only detectable phase. The sample has a noticeably higher specific gravity than most others collected because of fine grain size and low porosity.

Thin section

Consists of relict fragments of partially to completely replaced bioclastic fragments in an almost continuous amorphous micrite. In a few areas the skeletal elements are less completely replaced but the patches of more coherent rock which this produces are too isolated to impart adequate strength to the stone to make it a good building material.

Most identifiable framework fragments are bryozoan skeletons. A few echinoderm plates and spines are well preserved. A feature not seen in other specimens is coarse and fine, subparallel, calcite lamina. Their orientation is probably parallel to the weak bedding visible in hand specimen, but the material is not confined to a single bedding plane. Some laminae are double walled and often multichambered, and simulate organic forms but may be inorganic coatings on the walls of solution pipes or planar cavities.

Following alizarin-red staining, the micritic matrix appears red without magnification but brown in transmitted light under low magnification. High magnification shows that both stained and non-stained amorphous carbonate are closely intergrown in the matrix. The calcitic material is probably derived from almost completely dissolved skeletal elements but may include chemically precipitated calcium-rich carbonate as well as brownish ankeritic carbonate.

Comment

The extensive alteration of the rock masks the fact that the original sediment was identical to that of other samples in this suite, and that the bryozoa are all of the same species. As amorphous matrix is dominant, producing a friable stone, it is not surprising that material from this quarry is used only for agricultural lime.

Specimen 7022 RS129, TS C44845

Locality

Kain and Shelton Quarry; current workings. Quarry operator described material from this quarry as 'top-quality white'.

Hand specimen

Yellowish white calcarenite which varies considerably in coherence. At one end the stone retains sharply cut corners and edges, at the other end the grains are so weakly bonded that they crumble away at the pressure of a finger. Grain size is even except for a few sheet like forms of inorganic orign. Tubular fragments are highly abundant and, because of relatively light alteration, are readily recognisable as organic forms from their delicate ornamentation. Their internal structure is cellular. No powdered micrite is evident.

Thin section

The material sectioned is a highly porous, open framework consisting of bryozoal fragments, with abundant echinoid spines and plates.

Colourless carbonate cement is only moderately abundant and appears to be almost completely absent from some fragments. Very few pore spaces are filled. Importantly as far as the suitability of the stone as a building material is concerned, the cement is highly crystalline. Even though many framework elements are in contact at only a few points, adherence at these points is strong because of the strength of crystalline rather than amorphous carbonate.

Comment

The critical factor in the coherence of the stone appears to be the nature, not the abundance, of the cement.

Specimen 7022 RS 130, TS C44846

Locality

Knight and Pritchard Quarry; current workings.

Hand specimen

The rock is a purer white than RS129 but is still slightly creamy. Faint chalky white powdery marks are visible and some amorphous micrite is probably present. Grain size appears finer than in RS129 and the shape of individual fragments is poorly defined. Considerable recrystallisation is predictable but the matrix and cement must be dominantly crystalline as the stone is coherent.

A few coarse grained shell fragments, possibly of burrowing molluscs, are visible.

Thin section

A high degree of recrystallisation and the presence of crystalline interstitial material were confirmed. There is more cement than in RS129 and most framework fragments are covered with enough crystalline, dolomitic carbonate to conceal their original shape.

By far the major part of the bioclastic material is bryozoal but echinodermal fragments are again highly abundant. A few foraminiferal remains are present.

The fine, powdery, amorphous micrite which was detected in hand specimen occurs in internal pore spaces of bioclastic fragments but appears to have been removed from intergranular spaces.

Comment

The sample shows strong recrystallisation but, because interstitial material is mainly crystalline represents a good building stone. Amorphous micrite is retained in internal pores but has been removed from interstices between grains, suggesting that powdery micrite was deposited during an early stage of alteration. This was followed by removal of powdery micrite and deposition of crystalline carbonate as a matrix and cement.

Specimen 7022 RS131, TS C44847

Locality

Knight and Pritchard Quarry; recently reopened old quarry.

Hand specimen

The sample is fine grained with abundant matrix and overall is of a yellowish cream colour. However, bryozoal fragments are distinctly whiter than the creamier matrix. The form of individual fragments is often obscure and there is a weak preferred orientation which may be bedding. From the coherence of the block, which is cut at an angle to the fabric, the matrix must be largely crystalline. Some chalky powder is present.

Thin section

The overall fabric is highly recrystallised with a dominantly crystalline matrix. In patches the yellowish, powdery micrite is present in substantial quantity but not apparently in enough abundance to affect the strength of the stone.

The bioclastic detritus is almost entirely derived from bryozoa. Echinoderm fragments are very much less abundant than in RS129 and very few molluscan and foraminiferal remains are present.

Comment

Despite the presence of patches of interstitial amorphous micrite, the crystallinity of the highly recrystallised sample is sufficient to impart the properties of a good building stone.

Specimen 7022 RS132, TS C44848

Locality

Stafford and Blackall Quarry; current workings.

Hand specimen

Creamy white, slightly friable but coherent calcarenite which dries to 'first-grade white' colour. It is rich in matrix, relatively fine grained and with poorly shaped bioclastic fragments. There is no evidence of chalky white powder. A few grains are vitreous and pink in appearance.

Thin section

The sample is very similar to RS131 with an abundance of bryozoal detritus and of well crystallised dolomitic cement. The cement fills some of the interstitial spaces in the form of a matrix but many pore spaces remain open. Echinodermal remains are moderately abundant.

A little amorphous micrite is present in internal pores.

A distinguishing characteristic of this specimen is the presence of a few silicate grains. Most are yellowish, poorly crystalline minerals, probably chlorite, but one is a rounded detrital grain of well twinned microcline.

Comment

Again the critical factor necessary for good building stone appears to be the presence of a crystalline cement.

Specimen 7022 RS133, TS C44849

Locality

Stafford and Blackall Quarry; current workings.

Hand specimen

The specimen appears identical to RS132, and is of good quality building stone.

Thin section

There appear to be no significant differences between specimens RS132 and 133. The only minor differences noted in thin section are the absence of chlorite and microcline and the presence of very rare quartz and dolomite in RS133.

Comment

The two specimens examined from this quarry appear to be of good quality.

Specimen 7022 RS134, TS C44850

Locality

Stafford and Blackall Quarry; recently worked but now abandoned because of prominent fine-grained, yellow-stained silty beds causing splitting of all ashlars cut. Sample collected to represent these ?glauconitic bands and not of typical ashlar material; RS 132 and RS 133 are more representative.

Hand specimen

Unlike RS132 and 133 the sample is a slab in which planes, presumably bedding planes, are marked by penetration of yellow brown stain. The calcarenite has a laminated appearance but the laminar markings are discontinuous and uneven in shape. The granular structure is fine and well sorted with poorly preserved skeletal fragments. A scan by XRD recorded calcite with traces of potash feldspar and apatite (Appendix A) and although very fine grained the rock is essentially a calcitic limestone.

Thin section

The section includes one of the heaviest lines of staining, separating two highly porous zones. The brown stained band cuts a fainter oriented fabric at a low angle.

The major, porous parts of the rock consist of highly corroded skeletal remnants surrounded by well crystallised dolomitic micrite. The fabric is penetrated by a large number of cavities, almost certainly the product of substantial dissolution by pore fluids. This fabric produces an excellent building stone owing to its substantial, well crystallised matrix.

The properties of the rock as a building material are downgraded by the presence of the weak brown bands along which the rock parts. In thin section these are seen to consist of a brown, amorphous micrite similar to that described in RS125 and in other specimens exhibiting poor strength. In RS134 the material is darker than in other samples and under high magnification is seen to consist of yellow, amorphous carbonate and a pink calcitic carbonate which is at least in part the remains of bioclastic fragments. The yellow carbonate may be of ankeritic composition but is not crystalline enough to register in an X-ray diffraction scan (Appendix A).

No apatite or potash feldspar were recognised but a small grain of quartz was identified.

Comment

The thin, yellow-brown bands of micritic alteration are secondary features and are at a slight angle to an oriented fabric, presumably bedding. All quarry operators report that these bands are rare but cause splitting of ashlars and often lead to temporary abandonment of the quarry.

Specimen 7022 RS135, TS C44851

Locality

Johnson Quarry; abandoned ashlar quarry but previous rejects are being cleaned out by Gambier Earthmovers Pty. Ltd. for use as road rubble.

Hand specimen

Coarse to fine bioclastic fragments are bound in a fine grained matrix. The rock is yellowish cream and somewhat variable in strength. Most of the sample is of adequate strength but patches in which the grain size is very fine, but not powdery, are very low in strength. One large fragment may be part of an echinoid test.

Thin section

Shows an open framework of rather finely fragmented skeletal material, mainly of bryozoa but including abundant echinoderm plates and spines and a little foraminiferal remains. Fragments are bound by fine grained carbonate which is crystalline in places and amorphous elsewhere. Solution effects have been substantial but have not produced a uniformly well-bonded rock.

Comment

Quality of this rock varies rapidly from point to point depending on the crystallinity of the matrix.

<u>Specimen 7022 RS136, TS C44852</u>

Locality

Treffers Quarry; current workings. Sample is similar to RS 134 being selected to represent the very fine-grained, yellow-green silty bands along which ashlars split resulting in rejection. The sample should not be regarded as representative of ashlars produced from PM 132.

Hand specimen

Chalky white, very friable, powdery calcarenite with insufficient strength to remain coherent under finger pressure. The matrix is powdery and fine grained but sorting is very poor and bryozoan remains up to 200 mm long are scattered throughout. There is a weak and irregular bedding at a low angle to the length of the cut slab.

Although very fine grained, clay is absent and only calcite and a trace of quartz were detected by X-ray diffraction (Appendix A).

Thin section

The section is not representative of the whole slab because the epoxy resin had not penetrated areas with the finest matrix. Some of the section is composed of material with a micritic matrix.

Both crystalline and amorphous micrite are present, the former in an open, porous structure similar to that of the best ashlars and the latter in a matrix-rich lithology.

Much of the framework material is highly fragmented but the presence of large pieces of bryozoan skeleton suggests that fragmentation is not solely the result of erosional forces. The calcite fragments are highly corroded and the more delicate parts are fragmented in place by micritic replacement. In amorphous micrite framework elements have been reduced to small relict fragments without any clear relationship to each other.

Several small grains of quartz and a few flakes of poorly crystalline chlorite or glauconite were observed but it is not clear whether they are detrital or are the product of precipitation from pore solutions. Some quartz fills fine pores and shows traces of a fibrous, chalcedonic structure while other grains are angular and appear to extinguish sharply. Quartz of both origins is probably present.

Comment

As expected, this low strength calcarenite can be petrographically distinguished from calcarenite of typical ashlars. As for RS 134, the poor quality is linked to a very fine-grain size which is apparently the product of alteration rather than sedimentation. The non-carbonate fraction is low but significantly higher than in other samples.

Specimen 7022 RS137, C44853

Locality

Same as RS136, Treffers Quarry; current workings.

Hand specimen

Good-quality building stone, corners remain sharp and the stone is coherent under normal stresses. The load bearing capacity would be high. The colour is white with a very weak creamy tint. A few patches of chalk white powder suggest the presence of amorphous micrite. The fabric is porous but not friable and the rock is poorly sorted.

Thin section

The rock is an open framework of bryozoan fragments of varied size with abundant echinoderm skeletal plates. A few foraminiferal tests are present.

The framework material has been replaced by micritic carbonate but not on a scale as extensive as in RS136. Most skeletal fragments are still complete but are coated with a non-staining crystalline carbonate. Presumably this cement accounts for the strength of the stone. Patches within the fabric are not porous but include a micritic matrix which is finer grained than the crystalline cement and may be amorphous. In some areas micrite appears to be different from that in other samples in that it has taken up alizarin red in an overall stain rather than just in relict fragments of the framework. In other areas micrite has not taken up the dye. It may be assumed that both calcite and dolomitic matrix are present. Within areas of matrix, the corrosion of framework elements is much greater than elsewhere.

Comment

Lithological variance between RS 136 & 137 is transitional rather than radically different. Less corrosion, replacement and fragmentation of the original framework and a greater development of a crystalline cement have resulted in the high quality of RS137 in contrast with the bedded, low strength calcarenite of

RS136.

Specimen 7022 RS138, TS C44854

Locality

Lawson Quarry; current workings.

Hand specimen

Calcarenite very similar to RS 137 but of even better quality, the most notable difference being a higher content of echinoderm skeletal debris, including large fragments of echinoid tests. The absence of chalky patches improves the quality relative to RS137. The framework is open with varied grain size but little matrix.

Thin section

One bryozoal fragment is 25 mm long but the majority of grains are smaller. Some skeletal material has been fragmented and forms a relatively coarse-grained matrix. Many fragments appear to be parts of an original large fragment and are thus probably the result of corrosional rather than abrasional fragmentation. If this is so there may have been an interstitial micrite which has subsequently been removed in solution. A thin but continuous coating of crystalline micritic cement accounts for the excellent coherence.

Comment

This sample represents calcarenite which is most suitable for use as building stone, possessing an ideal fabric, an open framework without matrix but with a cement that does not have to be thick but must be crystalline.

Specimen 7022 RS139, TS C44855

Locality

Lawson Quarry; current workings.

Hand specimen

Good quality coherent calcarenite, apart from one line of chalky material. The structure is mainly open but well cemented and the corners of the block are sharp. Colour is creamy white except where chalky.

Thin section

The section is cut from coherent material composed of an open framework of skeletal debris. This is mainly composed of bryozoan debris but includes a moderate amount of echinoderm spines and scales and a few large mollusc (?) fragments.

Micritic cement of non-staining carbonate is present as thin coatings and partial to complete fillings of internal pores. Interstitial spaces are generally empty. Very little amorphous cement is present, but a few traces remain in internal pores.

Comment

The rock shows evidence of substantial recrystallisation but the last episode appears to have dissolved out most of the amorphous micrite and deposited enough crystalline cement to form a coherent framework. The size of the detritus is very varied with many smaller fragments which are apparently derived by in situ fragmentation of larger pieces by post-depositional processes.

Specimen 7022 RS140, TS C44856

Locality

Lawson Quarry; current workings. Selected to represent typical ashlar from extreme northwestern end of main ridge; quarry rejects range from brilliant white to yellowish cream.

Hand specimen

Yellowish cream calcarenite is weakly bedded and is friable, powdery and easily broken. A few patches are well cemented and coherent but most of the stone consists of fragmented, bioclastic debris in a weak matrix.

Thin section

The section is very similar to that of RS139 since both were made from a coherent part of the respective specimens. There is possibly slightly more amorphous matrix in RS140 but the difference is slight. The framework is open with a high porosity and a well-crystallised micritic cement.

Comment

Although the thin section indicates good-quality limestone, the hand specimen is considerably more friable and powdery suggesting that the degree of cementation varies rapidly over short distances, demonstrating that thin section is not always representative of the quality of the rock in a particular quarry.

Specimen 7022 RS141, TS C44857

Locality

Fletcher Quarry; current workings. From the same locality, and equivalent, to, RS 163.

Hand specimen

The sample is yellowish cream in colour and very varied in texture. Most of the block is coarse grained, open in structure and with good coherence. Bioclastic fragments are sharply defined. The sample has broken off a larger slab along a line of poor quality stone where the texture is finer grained with poorly defined fragments in a friable matrix.

Much of RS141 is as strong as the best Marte stone but the overall quality as a building stone is decreased by the presence of poorly cemented areas.

Thin section

Most of the section is composed of calcarenite with an open structure and well-developed, crystalline cement. At one end poorly crystalline micrite occurs in some interstitial spaces and represents the poorer quality stone noted in the hand specimen.

Skeletal material is mainly bryozoal and varies from very large fronds to debris that has been fragmented _in situ_ by corrosive solutions. Echinoderm fragments are present but no foraminiferal remains were observed.

Recrystallisation has been intense in some places but precipitation of crystalline cement is sufficient to restore the coherence of the rock in most places.

A few grains of quartz are present. Extinction is highly undulose and the quartz is probably of chalcedonic origin.

Comment

Grain size variation indicates that the original sediment was similar to that in most other samples. Extensive _in situ_ fragmentation of framework material by dissolution in pore fluids has not proved deleterious to most of the rock because extensive deposition of crystalline micrite has restored the coherence lost by dissolution. Only in patches where the micrite is poorly crystalline has the final strength of the stone been reduced.

The specimen is a stronger yellow colour than RS142 and appears to be somewhat more consistent in texture.

Specimen 7022 RS142, TS C44858

Locality

Fletcher Quarry; current workings but sample is from a higher bed than RS 141 in the adjacent quarry. Leaseholder states that ashlars from this locality are 'harder' than those produced from the area where RS141 was collected.

Hand specimen

Grain size is relatively coarse with a prominent echinodermal component. A few large fragments may be of molluscan origin. There is little matrix and fragments are sharply defined.

Thin section

Echinoderm plates are a major framework component but bryozoal debris is still the most abundant constitutent. Grain size is very varied and there appears to be more matrix than was predicted from the hand specimen. Most of the micrite is crystalline but a substantial proportion appears to be poorly crystalline to amorphous. The section may represent less coherent material than the average of the block.

RS142 is distinguished from most of the other samples examined by the presence of a few quartz and microcline grains and a small amount of poorly crystalline, yellow chlorite. Most samples which silicate material has been identified have come from the eastern line of quarries.

Comment

RS142 represents calcarenite suitable for production of good ashlars but petrographic examination suggests that the amount and type of matrix, and hence the quality of the stone, may vary from place to place. The presence of silicate grains and relatively coarse bioclastic material, particularly echinodermal fragments, suggests that the environment in this depositional area may be slightly different from the conditions prevailing over most of the shelf. The difference may lie either in proximity to the shoreline or in the strength of a bottom current. This may be a factor influencing the quality of the stone but is probably subsidiary to the nature of the cement.

Specimen 7022 RS143, TS C44859 Dolomite

Locality

Carraill Quarry; ML 3510; current dolomite quarry.

Hand specimen

Hard, highly crystalline, porous, bright orange dolomite with a weak fabric.

Thin section

The rock consists of a mosaic of coarse grained, euhedral to anhedral crystals of dolomite. Only one fragment of a calcite skeletal element and very few inclusions which still retain an organic form following dolomitisation were observed although the dolomite is presumed to have replaced Gambier Limestone.

The sample is penetrated by a system of large pores but most of the fabric is of closely interlocked dolomite grains. The dolomite is often zoned and carries a zonal or sectional pattern of fine opaque granular inclusions. In general the patterns are not recognisably organic.

Comment

The dolomite is interpreted as a highly altered version of Gambier Limestone and would make a high-quality building stone in its own right.

Specimen 7022 RS144, TS C44860 Dolomite

Locality

Holloway Quarry; ML 4711; current dolomite quarry; beside Princes Highway.

Hand specimen

The rock is a light yellowish brown in colour but otherwise appears similar to RS143.

Thin section

The rock appears identical to RS143 in thin section since the colour is not apparent. Fine granular inclusions are again common but form inorganic rather than organic patterns. The lining of one cavity has taken a faint pink colour from the alizarin red dye but no other carbonate grains appear to be calcite.

Comment

The dolomite is very similar to RS143, the minor difference in colour possibly originating from the state of oxidation or hydration of iron which forms the fine grained inclusions.

Specimen 7022 RS 145, TS C44861

Locality

White Quarry; abandoned quarry - not worked since about 1956. Not located on either of the two main lines of quarries. Quarry faces are soft and friable, with pronounced grain size variations defining bedding. Overall, colour is creamy but with a slight brownish tinge.

Hand specimen

The rock consists of a loose, friable framework of largely tubular bryozoa which appears to be almost without any cement or much recognisable matrix. The grain size is mainly fine but some large fragments, possibly of echinodermal tests, are visible. The rock has a weak directional fabric.

Thin section

This sample demonstrates how the presence of only small amounts of amorphous to poorly crystalline micrite can markedly reduce the coherence of the whole stone. Both well crystallised and amorphous carbonate are present in a patchy matrix. Much of the micrite appears to be intermediate in crystallinity. In thin section without magnification micrite patches are pink but under high magnification are seen to be largely composed of yellowish brown, non-staining carbonate.

Framework fragments are often far apart and not in mutual contact in the plane of section. The coating of cement is often almost absent and the friability of the rock is evident. Echinoderm debris is frequent among the bryozoa.

Rare silicate grains are present and include microcline, quartz and a chloritic material.

Comment

RS145 is possibly an example of a lithology from which matrix has been dissolved but which has not acquired an adequate crystalline cement to give coherence. Alternatively an existing crystalline cement may have been leached out by very recent pore solutions. This sample contrasts with those from the two main lines of quarries which have a crystalline cement coating bioclastic components and/or abundant matrix. If all material from White Quarry had properties similar to RS 145 it is not surprising that this quarry was abandoned.

Specimen 7022 RS146, TS C44862

Locality

Telford Quarry (Section 145); small abandoned quarry with no recorded production.

Hand specimen

Very pale cream, almost chalky white calcarenite mainly composed of fine grained, close textured skeletal fragments in a micritic matrix. Despite the matrix and a slight powdery chalkiness, the rock is strong enough for the corners to resist breakage under the pressure of finger and thumb. The rock combines good colour with good strength.

Thin section

The rock has a high porosity which extends to the patchy but widespread matrix as well as the framework. Matrix areas are small enough and open enough to permit a relatively high degree of crystallinity. Very little amorphous material is present although degree of crystallinity is somewhat varied. There is a tendency for some areas of micrite to extinguish rather imperfectly but simultaneously as if the whole mass is developing as a single coarse grained carbonate crystal.

Framework grains are mainly bryozoal but significant amounts of echinodermal and foraminiferal material are also present. Many internal cavities are filled partially or completely with micrite but interstitial cavities are open and fragments in the cavity walls are coated with only thin layers of crystalline cement.

Comment

Although the rock contains a substantial matrix it is of good building quality. This is an example of the importance of a well crystallised cement. Probably because the matrix is dispersed in small patches and accessible to aqueous solutions through a high porosity, the micritic component has been relatively well crystallised and adds to rather than detracting from the coherence of the whole structure. There thus appears to be a positive correlation between porosity and strength.

Specimen 7022 RS147, TS C44863

Locality

Gericke Quarry; quarry abandoned and now forms part of McNamara Park.

Hand specimen

Creamy white, porous, friable calcarenite, strength is low and some areas are rich in matrix. The framework is composed largely of tubular bryozoa. Minor specks of bright pink calcite are present.

Thin section

The sectioned sample is open with a crystalline cement and by its appearance should make a good ashlar. In fact the chip from which the section was cut is more coherent than the main part of the sample. The porosity of the chip is demonstrated by the extreme penetration of the epoxy resin. Thin layers of micritic cement are generally well crystallised.

The framework is largely bryozoal but includes a significant echinodermal component and a few foraminiferal tests. Some skeletal material has been fragmented in place by corrosion.

Comment

The thin section suggests this rock would produce a good ashlar but the overall grade of stone from the quarry was probably low because of inconsistency on the scale of a building block.

Specimen 7022 RS148, TS C44864

Locality

Kain and Shelton Quarry; recently quarried but not presently being used.

Hand specimen

The rock is creamy white, friable and of low strength being crumbled between finger and thumb. Grain size is medium to fine overall with a prominent finely granular to micritic matrix. A few large bryozoal fragments are scattered through the rock but most of the framework is finer than the average of the samples examined.

Thin section

Again the sample sectioned appears to be of excellent quality and is seen to be highly porous from the large quantity of resin absorbed during impregnation. The micritic cement is highly crystalline and there is no detectable concentration of amorphous micrite.

The framework is largely bryozoan but includes abundant echinodermal and foraminiferal fragments. Many skeletal elements are fragmented in place.

Comment

The thin section shows high quality stone but the hand specimen suggests patchy development of the crystalline cement, hence ashlars will be of variable quality.

Specimen 7022 RS 149, TS C44865

Locality

O'Leary Road Quarry; five kilometres WNW of the centre of Mt. Gambier.

Hand specimen

The rock is a yellowish cream colour and is relatively coarse grained with many large bryozoa and echinoid fragments. The fabric is varied and some areas are fine grained and matrix rich. Patches of chalky material are frequent, most are only a millimetre or two across but some are up to seven millimetres across. The rock is harder overall than RS148 but is probably inconsistent on the scale of a building block.

Thin section

In contrast with RS 147 and RS 148 the sample sectioned appears to be of poorer quality. Substantial masses of micrite are evident, much is amorphous or very poorly crystalline. Skeletal material within areas of micrite tends to be corroded, often almost to vanishing point. Porosity is low.

The framework includes a high proportion of calcite echinodermal fragments but at least one large mass of calcite with a high crystallinity is probably inorganic in origin and represents the infilling of a solution cavity.

Specimens from the eastern line of quarries in the Marte area are distinguished by a small but significant content of silicate minerals. However, specimen RS149 contains even more grains of quartz as well as a yellowish, amorphous chloritic mineral. The grains are very fine and tend to occur in internal cavities in bryozoal material. Most are probably precipitated chemically but detrital grains may be present.

Comment

The hand specimen, which has not been cut into a slab for building purposes, appears to be of good quality stone. The thin section, however, illustrates that poor quality material is also present and suggests that the stone may be too inconsistent to make good ashlars.

Specimen 7022 RS150, TS C44866

Locality

Mount Salt Quarry. Abandoned quarry - no recorded production since 1958. Material from this quarry looks identical to RS 152 from Stafford Quarry. The sample presumably represents a higher stratigraphic unit to that exposed at Marte.

Hand specimen

Very friable calcarenite with very low strength. Chalky patches are common. Much of the skeletal debris is of coarse grain size but there is a substantial fine grained matrix. Some very large fragments may be of molluscan origin.

Thin section

Friability and low strength are due to an abundant micritic matrix which is optically amorphous to weakly crystalline. Without magnification the micrite appears massive and has stained red during testing for calcite. In transmitted light under magnification much of the material consists of yellow brown carbonate without identifiable optical properties and with numerous inclusions of red stained carbonate and poorly defined patches of pink carbonate. The former may be relict fragments of original organo-carbonate skeletal material and the latter a calcitic micrite.

Framework fragments often contain clear, crystalline micrite in internal cavities and a few are coated with similar material which could form a cement. Most interstices between framework fragments are filled with amorphous, powdery micrite and surfaces capable of being cemented are rarely in contact. Most framework carbonate is strongly corroded and probably recrystallised but much is still identifiable. Bryozoal material is most common but both echinodermal and foraminiferal remains are present.

Some silicate grains are present, quartz is present in grains both with sharp extinction and with undulose extinction indicating an amorphous origin. The yellowish mineral without identifiable optical properties is also present and is probably a chloritic or glauconitic mineral.

Comment

The specimen demonstrates clearly that the presence of amorphous micritic carbonate lowers the coherence of Gambier Limestone and significantly reduces its suitability as a building material. There is some evidence that a crystalline cement can be a precursor to amorphous micrite as well replacing that same amorphous micrite.

Deposition, resorbtion and replacement of different types of micrite may be a continuous sequence of events, possibly repeated many times. The phase deposited inevitably depends on the conditions of deposition and an alternation of different forms of carbonate appears possible.

Specimen 7022 RS151, TS C44867

Locality

Pareen Quarry; abandoned quarry with no recorded production since 1951. Quarry walls do not exhibit bedding and the material is particularly even grained. Ashlars from this quarry are described as 'puggy' i.e. chalky and 'fret' badly in use. The 'puggy' character causes saws to clog while cutting stone and also results in poor-quality road rubble.

Hand specimen

Massive, fine grained calcarenite with some large bryozoal remains, whiter in colour than most other samples in the suite. Overall block strength is reduced by the presence of very chalky patches.

Thin section

Apart from scattered, very coarse fragments of bryozoal and echinodermal origin, the fabric consists of relatively fine grained skeletal material surrounded by mainly amorphous micrite. Much of the bioclastic material has been fragmented by dissolution and the effects of corrosion of the original framework are widespread.

Although much bioclastic debris is unrecognisable, bryozoan fragments are apparently the most abundant form of skeletal material and echinodermal material is common.

A few fine grains of quartz and amorphous chloritic or glauconitic mineral are present.

Three types of matrix are present. The most abundant is fine grained, brownish, apparently amorphous and probably ankeritic micrite. This is somewhat patchy in distribution but widespread over the section. Porosity is low. The second most abundant matrix comprises fragmented, red-stained skeletal debris. The third matrix type not encountered in the other samples is euhedral to subhedral carbonate rhombs. These are fine grained, patchily distributed inclusions in the micrite. The carbonate does not stain with alizarin red, is colourless and is either dolomite or magnesite, probably the former. At high magnification the crystals, though euhedral in form, are seen to be poorly crystalline. This indicates recrystallisation, or partial destruction of a crystal lattice, assuming that the original euhedral crystals were precipitated with a perfect crystal structure.

Thin layers of crystalline micrite still persist as coatings on internal pores in bioclastic fragments.

The thin section is of poorer quality rock than the specimen as a whole.

Comment

The sample well illustrates the factors leading to poor strength in the limestone. Not encountered in other samples is evidence of the precipitation and subsequent recrystallisation of euhedral dolomite crystals within the micritic matrix. This is an additional indication of complexity in the history of reactions between the carbonate framework of the limestone and solutions percolating through the pore system.

Specimen 7022 RS152, TS C44868

Locality

Stafford Quarry.

Hand specimen

The sample retains a sharply cut edge between two faces but the rest of the block has broken up along faces with abundant chalky and highly friable matrix. These faces can be gouged by a fingernail. Fossil shapes may be discerned on the cut faces although most of the material is poorly defined. On the broken faces only a fine grained, featureless and crumbly material is exposed.

Thin section

Without magnification the section shows large, irregular, poorly defined patches of micrite which have retained the alizarin red. Under magnification in transmitted light the micrite is seen to be largely dolomitic, that is clear and not stained. Scattered calcitic fragments of bioclastic origin are included in the micrite and are stained red. Small, irregular areas in the micrite are stained pink and presumably consist of magnesium-rich calcite or calcium-rich dolomite.

Euhedral rhombs of dolomite are more abundant, larger, better shaped and better crystallised than in RS151.

Internal pores in the rare complete skeletal fragments retain some crystalline micritic cement.

A little quartz and yellow chlorite are present, as well as very rare flakes of muscovite.

Comment

The abundant, poorly crystalline matrix markedly reduces strength of the rock.

Specimen 7022 RS153, TS C44869

Locality

Un-named quarry in hd. Blanche, section 526; about 1 km west of MacNamara Park.

Hand specimen

The calcarenite is of moderate strength but contains a high proportion of fine grained matrix with mainly fine-grained skeletal fragments making up the framework.

Thin section

Bioclastic fragments are less fragmented than those in RS152. Although matrix is almost as abundant as in RS 152, it differs in three respects. Firstly it is more porous or open in structure, secondly it is colourless rather than brown or pink stained and thirdly it is more crystalline. These differences evidently exert a significant influence on the strength of the stone.

Skeletal material is largely bryozoal in origin but includes echinodermal plates and spines. Corrosion is evident but not as far advanced as in RS152.

Fine, angular grains of quartz are common and a few grains of yellowish chloritic mineral are present.

Comment

The more crystalline, porous matrix in this sample compared with RS 152 results in a stronger building stone.

Specimen 5, TS C42180A

Locality/Hand specimen

The sample of bryozoal limestone was obtained from the Supreme Court Building, Victoria Square, Adelaide, although only a small portion of the building is Gambier Limestone. The block had been exposed in an exterior wall for approximately 120 years. It is not known from which quarry the block was obtained.

Thin Section

The thin section has not been stained by alizarin red dye.

Bryozoal fragments, generally less than 2 mm across, make up the major proportion of the framework. They are almost exclusively reticulate in form; the tubular forms described in some specimens from the Mount Gambier area are rare. They are light brown in colour and composed of finely crystalline carbonate.

Although bryozoa are the major source of bioclastic material, the specimen is rich in echinoderm fragments concentrated in patches and distributed widely throughout the rock. Fragments of spines and plates are present and comprise more coarsely crystalline carbonate than that in bryozoal fragments. Fragments of echinoid spines extinguish between crossed polarisers in optical continuity but a mottled appearance away from the extinction position suggests that the carbonate consists of parallel prismatic crystals rather than a single large crystal. Echinoid plates consist of a mosaic of fine crystals. Irregular margins to some of these plates suggest addition of inorganic carbonate.

Minor bioclastic material has been contributed by small gastropods and foraminifera.

Some crystalline carbonate material is without recognisable form and may be an inorganic, interstitial deposit from pore solutions. Patches of this material are up to 1 mm across and consist of a fine-grained mosaic of crystals similar to echinoid plates. The latter may have formed a nucleus on to which more carbonate was deposited to fill intergranular spaces.

A few scattered patches of interstitial material are of low birefringence and may be gypsum or kaolinitic clay. Alternatively, a little finely granular and poorly crystalline carbonate may be present. Large areas of almost amorphous carbonate are absent.

Comment

In samples 7022 RS 121-153 from Mount Gambier it was usually possible to distinguish framework, matrix and cement, but it is rarely possible to make these distinctions in this sample.

Occasionally, a triple layering is evident in which an original bioclast is coated on each side by a cement of crystalline carbonate. In a few places a mass of interstitial carbonate is identified as wholly or partly inorganic in origin. Generally carbonate is uniformly crystalline and material of different origins merges together and is indistinguishable.

The pervasive crystallinity is the main difference between this sample and other samples of Gambier Limestone. The abundance of echinoderm detritus is a minor difference. Staining by alizarin red would indicate how much of the recrystallisation was dolomitic. If recrystallisation is dolomitic, then this sample may represent early stages of dolomitisation towards end products such as RS 143 & 144, from Carraill and Holloway dolomite quarries respectively.

DISCUSSION

The physical properties of Gambier Limestone result from both conditions of initial deposition and, a subsequent, very complex alteration history.

Deposition

Wass et al. (1970) suggested that bryozoan-rich Eocene and Miocene calcarenites in the Eucla and Murray basins represent the "Tertiary counterparts of the modern bryozoan sands now forming on the continental shelf off southern Australia". Accordingly the environment of deposition of Gambier Limestone is shown in modern photographs of the forest of bryozoan communities almost completely covering the sea floor (Wass et al. 1970, p.67). Bryozoa flourish between depths of 100 and 250 m but are subjected to southwesterly currents strong enough to ripple the sand. Some winnowing of fine particles probably occurred and contributed to the observed lithological variations. Overall, depositional conditions were probably fairly uniform and the range of particle sizes relatively constant. Minor variations in the original sediment have been observed but are not believed to affect significantly stone quality.

The dominant bryozoan species forms a fan or fern shaped colony with a mesh-like or fenestrate calcareous skeleton. In a few samples bryozoa with tube-shaped skeletal elements predominate. Another variation is the relative abundance of echinodermal spines and plates. The abundance of foraminiferal remains varies considerably but delicate skeletal elements are more readily altered than thick carbonate and the variation may be the product of dissolution processes rather than of varied sedimentary environments.

Quartz, chalcedony, microcline and yellowish chlorite or glauconite are very minor components and any variation in content is unlikely to have any detectable influence on stone quality. Both very fine detrital clasts and chemically precipitated grains are probably represented. The highest concentration of silicates is in samples from:

- the Marte eastern line of quarries where all six samples examined contain traces of quartz, microcline or poorly crystalline, yellowish chlorite or glauconite.
- samples away from the main Marte area i.e. Mount Salt, Pareen, O'Leary Road, Stafford and White Quarries. All five samples examined contain traces to minor amounts of quartz and poorly crystalline, yellowish chlorite or glauconite, some of which are precipitated in internal cavities of bryozoal skeletons. 7022 RS 152 from Stafford Quarry near Mount Schank also contains rare muscovite flakes.

Only three samples out of twenty examined from the western line of quarries at Marte contain any silicates probably because of the rapid growth and deposition of bryozoa in this area. Bedding is massive although rarely evident with up to 4-5 m thicknesses without bedding plane partings. Away from the western line of quarries, bedding and bedding plane partings are more common, sedimentation was slower and terrigenous and diagenetic silicates are present. Silicates in limestone of the eastern line of quarries at Marte are probably derived from exposed Dilwyn Formation at the local, topographic high near 'Haven Hill' (see Flint, 1987).

Alteration

Post-depositional alteration is probably more important than sedimentological variations. The highly porous, calcitic framework was corroded and replaced to varied extents by solutions. Several forms of replacement carbonate have been recognised although in some cases precise identification is hampered by fine grain size and low degree of crystallinity. Much of the micrite is not identifiable optically and does not produce a distinct X-RD pattern. Calcite is identified by staining with alizarin red dye and the assumption is made that a brown or yellow colour implies an iron content in the carbonate. The distinction between iron-rich dolomite and ankerite is uncertain and magnesite may also be present.

Five alteration products of the original carbonate framework have been identified:

1) Crystalline dolomitic micrite.
2) Amorphous to poorly crystalline, iron bearing dolomite or ankerite.
3) Amorphous calcite.
4) Crystalline calcite.
5) Rhombic dolomite.

1. Crystalline dolomitic micrite

Must be present to produce a good-quality strong building stone because this cement imparts coherence to the block. Micrite comprises fine grained, clear carbonate with excellent prismatic external crystal form and presumably internal crystal structure. Assumed to be dolomite because it is not stained by alizarin red dye and apparently carries no iron. Based on optical properties the mineral could be magnesite but dolomite appears more likely. This type of micrite occurs as a filling to internal cavities in skeletal elements, often when it has been dissolved from the outside of the fragments. More importantly it occurs as a coating, often thin but apparently adequate, on the surface of framework grains and cements grains together where they are in contact.

2. Amorphous to poorly crystalline, iron bearing dolomite or ankerite

Whereas crystalline dolomitic cement improves ashlar quality the presence of amorphous carbonate is highly detrimental. This type of micrite forms the powdery, less coherent, chalky patches. Where interstitial to framework fragments it produces a friable, crumbly texture which reduces the strength of the block and probably causes rapid deterioration during normal weathering. The reduction in stone quality depends on the abundance of this type of micrite and lack of crystal structure. In a few samples poorly crystalline micrite was moderately abundant but strength of the stone was fairly high. The micrite apparently was either crystalline itself or had been permeated with sufficient crystalline dolomitic micrite to impart coherence. In thin section the material appears yellow or brown, probably depending on iron content, and includes abundant medium to fine grained calcite fragments. These relict fragments often represent original coarser bioclastic fragments which have been fragmented _in situ_ by corrosion.

3. Amorphous calcite

In many samples powdery micrite retains the red dye. Under magnification the micrite is seen to consist of closely intergrown patches of pink stained carbonate and yellow or brown carbonate. This third type of alteration product is simply a variant of the second type suggesting that the chalky micrite is an amorphous mass of carbonate with varying chemical composition and crystal structure. Sodium and strontium, as well as the major cations calcium, magnesium and iron, may be present.

4. Crystaline calcite

In a few samples a little well-crystallised calcite in the form of irregularly shaped grains occurs interstitially. This may be chemically precipitated calcite or, slightly recrystallised echinoderm fragments.

5. Rhombic dolomite

In two samples taken, perhaps significantly, closer to the coast than the others, euhedral dolomite rhombs are scattered through patches of micrite. This is a different type of dolomitisation than that which precipitated dolomitic cement and may be a preliminary stage in the process which produced the total dolomitisation of RS 143 and 144.

Most post-depositional alteration involves carbonate but in some samples a very minor silicate component is partly or wholly the product of chemical precipitation from pore solutions. Some rare quartz grains exhibit undulose extinction which may indicate a colloidal origin and the amorphous chloritic or glauconitic mineral is also presumably precipitated from solution. Sample RS 136 from Treffers Quarry contains traces of fibrous chalcedony infilling pores.

Several micrite types normally occur in any one sample and the paragenetic sequence is complex. Generally, in good quality stone the crystalline cement is the later of the two major micrite types while in poor quality stone chalky, amorphous micrite is the later and has replaced a crystalline cement. The sequence probably includes several episodes of deposition and replacement of one type of micrite by another. In a study of a dolomitised limestone aquifer in Florida, Randazzo and Bloom (1985) showed that dolomitisation occurred, and is occurring, at the interface between freshwater and saltwater where magnesium concentration is high. On the other hand, freshwater containing dissolved CO_2 preferentially takes magnesium into solution and leaches it from magnesian carbonates (Land, 1967). This complex sequence of replacement of one micrite by another is compatible with the history of inundation and re-emergence of the area of deposition of the Gambier Limestone. Migration of the freshwater/saltwater interface resulted from climatic and sea level fluctuations, and the volume of freshwater flushing varied with rainfall changes.

The crystallinity or degree of order in the crystal lattice, of a micritic carbonate is critical to the coherence of limestone building stone. The term 'protodolomite' has been coined (Graf and Goldsmith, 1956) to describe carbonates chemically akin to dolomite but lacking the ordered arrangement of true dolomite. Because an ordered arrangement does not occur naturally below 200°C, natural protodolomites are abundant (Bathurst, 1971). In Gambier Limestone amorphous structure apparently accompanies finely granular particle size and the deleterious chalky micrite is probably protodolomite. In addition to lattice disorder it is probably non-stoichiometric and may contain sodium, strontium, barium, iron and possibly chlorine as well as a varied proportion

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Coherestrong calcarenite suitable for building stone is characteris‹ the presence of a coarse bioclastic framework, a relatively se but well crystallised cement and a pervasive porosity: a ;ure which generally accompanies removal of chalky micrite and acement by crystalline cement.

In cont: friable, weaker calcarenite possesses a finely divided framrk with a matrix composed of highly corroded skeletal frents and powdery, amorphous micrite, and a significantlygher, or lower porosity than more suitable stone.

Discolouion by iron is probably related to movement of solutions asiated with modern, or at least Holocene, weathering. e yellow or creamy tints may be associated with more fundament characteristics of matrix and framework. Best white colour iprobably related to presence of chalky powder, which reduces sne coherence.

Possibly t major problem is that matrix variation is rapid and otherwise xellent stone may be downgraded by chalky patches. Consisency of quality, rather than the ideal properties in a smal sample, is a desirable feature.

SUMMARY

The Marte area 10 km west of Mount Gambier is the largest producer of building limestone in Australia with an output averaging 20 100 tonnes/year of ashlars over the last 36 years. All production is from Gambier Limestone, a bryozoal calcarenite with minor echinodermal and foraminiferal detritus deposited on the continental shelf during the late Eocene to Middle Miocene.

Suitability of calcarenite for use as building stone depends on the history of corrosion, replacement and deposition of micritic carbonate subsequent to sedimentation of a relatively uniform limestone.

The best quality (strongest) building stone comprises coarse grained skeletal material with a recognisable open fabric. There has been minimal corrosion of this bioclastic framework and deposition of crystalline dolomite as a thin cementing coating on framework grains.

Substantial corrosion of the framework and deposition of an amorphous carbonate of varied composition diminishes coherence of the stone, and at worst produces a chalky powder. The stone is less porous, fine grained and matrix rich with few relict fossil fragments e.g. Pareen stone.

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APPENDIX A

XRD IDENTIFICATION OF FOUR 'MARL' SAMPLES

AMDEL REPORT G 6330, Part 1

by

Michael Till

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amdel

31 May 1985

In reply quote: GS 1/16/0

Your Ref: 12/03/167 EX-350

Director General
Department of Mines & Energy
PO Box 151
EASTWOOD SA 5063

Attention: Mr. D. Flint
Mineral Resources

REPORT G 6330 PART 1

YOUR REFERENCE:	Application dated 14 May 1985
IDENTIFICATION:	7022 RS 125, 128, 134, 136
MATERIAL:	Four marl samples
LOCALITY:	Otway Basin, Gambier Embayment
DATE RECEIVED:	14 May 1985
WORK REQUIRED:	Determination of mineralogy

Investigation and Report by: Michael Till

Chief, Geological Services Section: Dr Keith J Henley

Keith Henley

for Dr William G Spencer
Manager, Mineral & Materials Sciences Division

fs

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MINERALOGY OF FOUR MARL SAMPLES

1. INTRODUCTION

Four marl samples were received from Mr. D. Flint of the South Australian Department of Mines and Energy with a request for determination of the clay mineralogy. However clay minerals were not detected in the bulk sample, and sedimentation and analysis of -2 μm fraction was subsequently not proceeded with.

2. PROCEDURE

The samples were analysed by X-ray powder diffractometry.

3. RESULTS

7022 RS 125

Calcite	D

7022 RS 128

Calcite	D

7022 RS 134

Calcite	D
Apatite	Tr
?K-feldspar	Tr

7022 RS 136

Calcite	D
Quartz	Tr

SEMIQUANTITATIVE ABBREVIATIONS

D = Dominant. Used for the component apparently most abundant, regardless of its probable percentage level.

Tr = Trace. Components judged to be below about 5%.

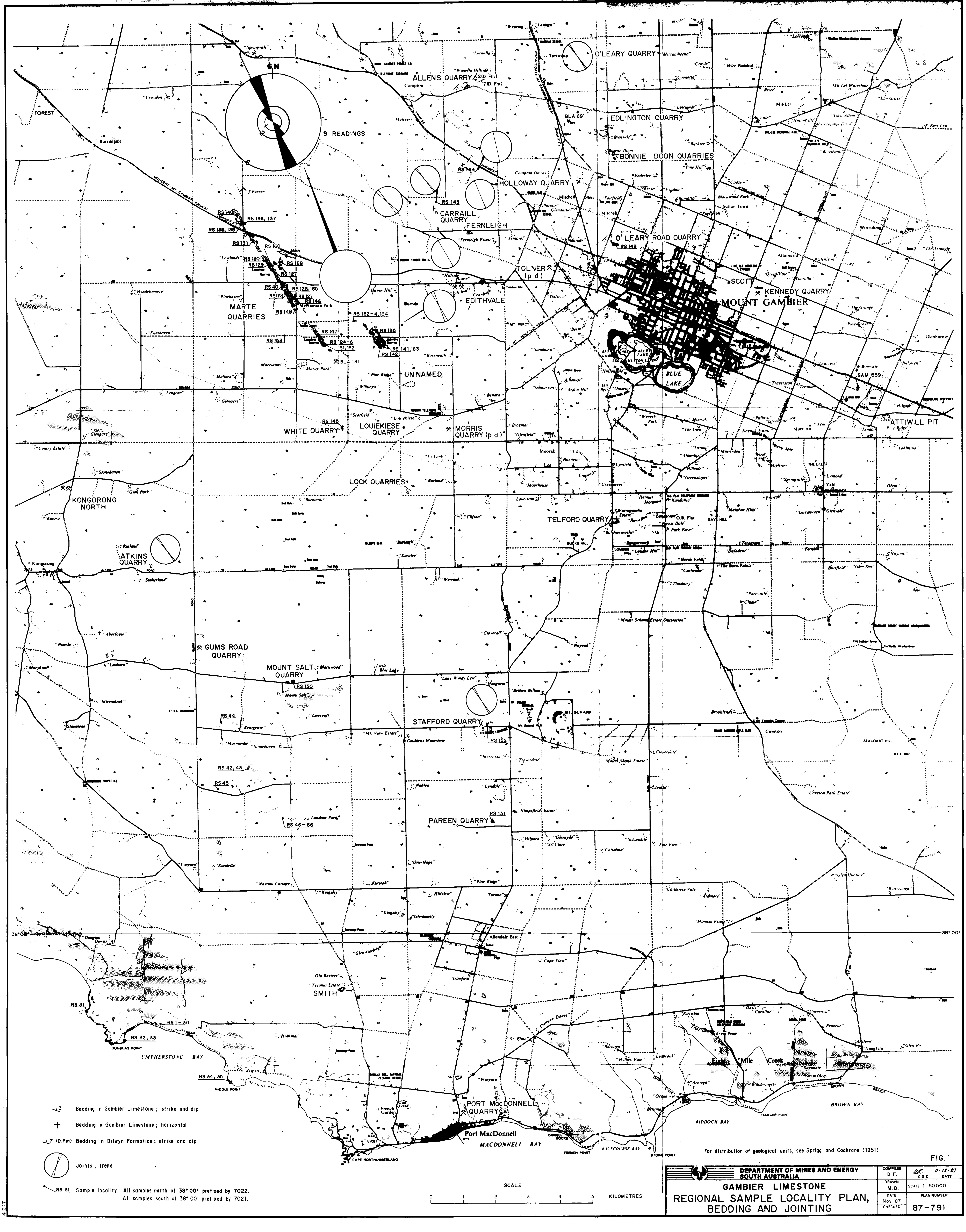

FIG. 1

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

GAMBIER LIMESTONE
REGIONAL SAMPLE LOCALITY PLAN,
BEDDING AND JOINTING

COMPILED	D.F.	11-12-87	
		CDO	DATE
DRAWN	M.B.	SCALE 1:50000	
DATE	Nov '87	PLAN NUMBER	
CHECKED		87-791	

QUARRY	TENURE	LOCATION (Hd. Blanche)	SAMPLE NUMBER, 7022 RS		
			Collected by L. C. Barnes (see Report Book No. 86/47)	THIS REPORT	Collected for material testing at AMDEL
KAIN AND SHELTON	PM 9	Sec. 26	40 (A2550/79) 41 (A2549/79)	121 122 123 148	165
BRUHN	PM 14 PM 15	Sec. 136		124 125 126	161 162
KNIGHT AND PRITCHARD	PM 115	Sec. 28		127 128 129 130 131	160 172*
McKAY, MAJOR AND JOHNSON	PM 125	Sec. 192		132 133 134 135	164
TREFFERS	PM 132	Secs. 28, 29, 30		136 137	
LAWSON	PM 134	Sec. 29		138 139 140	
FLETCHER	PM 153	Sec. 134		141 142	163
TELFORD		Sec. 145		146	
GERICKE		Sec. 138		147	
UN-NAMED		Sec. 526		153	

* used in calibration test pits at SADME, Glenside

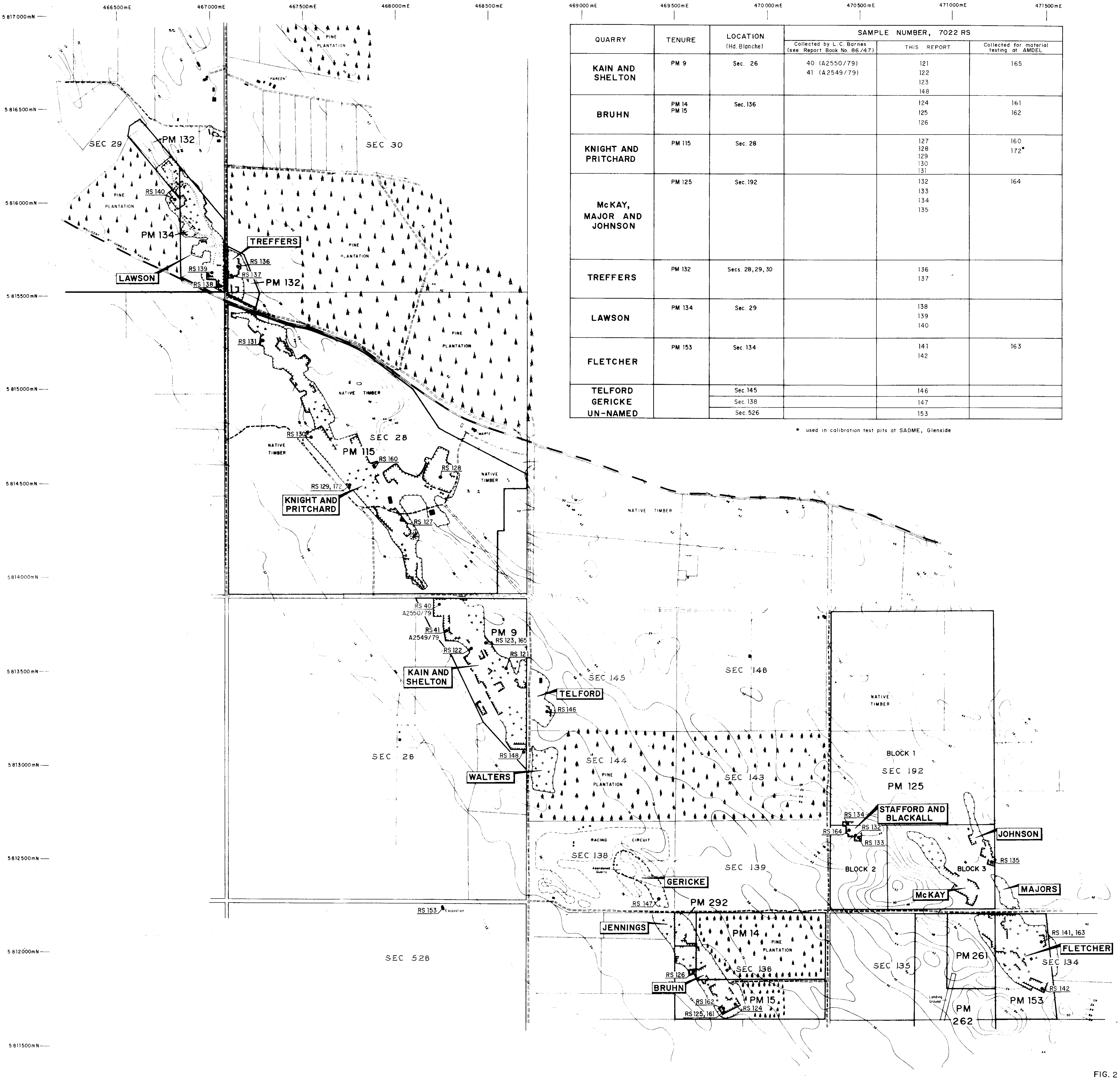

FIG. 2

Based on plan prepared by Photec Air Surveys Pty Ltd
from photography dated 3/3/1982

SCALE
0 200 400 600 800 1000 METRES

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED D.F.	C.G.O. 11·12·87 DATE
GAMBIER LIMESTONE	DRAWN M.B.	SCALE 1:10 000
MARTE AREA – SAMPLE LOCATIONS	DATE Nov '87 CHECKED	PLAN NUMBER 87-792