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RECORDS.

1954/65

THE FLOWERY GULLY LIMESTONE DEPOSIT, TASMANIA.

by

L.C.Noakes, G.M. Burton and M.A.Randal.

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CONTENTS.

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SUMMARY.

The Flowery Gully Limestone Deposit, twenty miles north of Launceston, was surveyed in detail to delineate the most suitable portions for supplying limestone to the Australian Aluminium Production Commission's plant at Bell Bay, five miles to the north east across the Tamar Estuary. Basic requirements for the limestone were that it lie in an area suitable for quarrying and have as low a silica and magnesium carbonate content as possible so that it could be used efficiently in the aluminium extraction process.

The preliminary reconnaissance revealed a stratigraphical chemical control and it was found possible to divide the section measuring 1,700 feet in true thickness into three stratigraphical zones, the topmost of which contains the purest limestone and is most suitable for Bell Bay; the middle zone contains isolated areas of high quality stone.

The more detailed survey to reveal quarryable stone in these two zones defined one major and one minor deposit in the upper zone and one minor deposit in the middle. These three deposits contain indicated and inferred reserves totalling 1,000,000 tons; of this figure 100,000 tons has an average grade of 0.4% silica and 5.7% magnesium carbonate and the remainder has a grade not exceeding 0.5% silica and 4% magnesium carbonate.

The investigation of the depositional environment revealed quiet and consistent conditions of deposition, which information was used to indicate possible areas for exploration for additional reserves when necessary.

Numerous bedded chert nodules are present in the high-silica-content areas of the middle zone. The origin of the silica of this zone was investigated chemically and petrologically, but the results were inconclusive. It was discovered however that practically all silica was syngenetic. It is now mainly in the form of quartz grains and in smaller amounts as a component of the small percentage of clay present; however where chert nodules are present the silica of the cherts is in the form of chalcedony.

Areas of marked dolomitization were noted, particularly in the upper and middle zones; they probably represent algal reefs (stromatoporoid bioherms). One of them had a lateral extent of at least 1,600 feet.

A distinct disconformity was revealed by the detailed mapping at the top of the limestone section.

INTRODUCTION.

The Australian Aluminium Production Commission plans to commence production at Bell Bay, which is on the Tamar Estuary, and 30 miles north of Launceston, early in 1955. They will need a regular supply of up to 16,000 tons per year of high-grade limestone for mixing with bauxite in the extraction of alumina by the Bayer process.

A review of possible sources of limestone in the north and north-eastern portions of Tasmania by the Tasmanian Mines Department (Hughes, 1950) indicated that the belt of limestone of Flowery Gully, 4 miles south-west of Beaconsfield, contained the deposits nearest to Bell Bay which were likely to be suitable. Beaconsfield is close to the Tamar Estuary but on the western side approximately opposite Bell Bay.

The Commission proposes to lighter the limestone across the Estuary in a hulk (the old survey ship "Phantom") which will hold approximately 600 tons, and to supply the hulk at Beauty Point, situated on the waterfront 3 miles north of Beaconsfield, by road haul of 7-8 miles from the Flowery Gully deposit. Access to the deposit is good because the Flowery Gully road runs the length of the limestone outcrops (2 miles by ½ mile); 4 miles of the haul at the Beauty Point end will be over a sealed main road but much of the 4 miles of gravel road from the deposit to the main road near Beaconsfield is at present badly pot-holed, and needs grading and surfacing before regular haulage begins.

Limestone deposits at Flowery Gully have previously been investigated by Twelvetrees (1903, 1919), Nye (1924), and Hughes (1950), as officers of the Tasmanian Mines Department. The deposits have also been referred to in other publications listed in the references at the end of this report.

Previous writers correctly refer to the deposits as "high-grade" because much of the stone is a very satisfactory source of lime for agricultural and most industrial purposes, and large tonnages satisfy the more critical requirements of the cement industry in which the content of magnesium carbonate should not exceed about six percent.

The Commission's requirements, however, are even more critical, and call for limestone with the lowest possible percentage of both silica and dolomite. Of these two the percentage of silica is the more critical because in chemical treatment some silica combines with soda, a relatively costly reagent introduced to leach alumina from the bauxite mix. Thus the silica content of the limestone leads to loss of soda, and on the Commission's figures an increase of only 1 percent. silica from 0.5 to 1.5 percent would entail loss of soda worth approximately £1,600 per annum. It follows that any silica content of the limestone is undesirable.

The requirements in regard to dolomite are not so clear cut: it is a diluent, and there is some evidence that increase in dolomite, perhaps above 6 percent, might decrease the efficiency of the chemical process. Dolomite content was therefore required to be as low as possible, with no fixed tolerance but with an arbitrary maximum of about 5 percent.

The quantity of limestone of suitable grade was not defined, but tonnage sufficient to feed the present lime kiln at the plant at maximum capacity (approximately 16,000 tons of limestone per year) for twenty years - 320,000 tons - was taken as the order of the reserves required. The Commission's problem was therefore to find within the limestone belt reserves of stone with the lowest possible silica and dolomite contents in situations favourable for economic quarrying, and by agreement with the Tasmania Mines Department investigation by the Bureau of Mineral Resources was requested.

METHOD OF INVESTIGATION.

The work was started on 7th April by M. C. Konecki, G. M. Burton, and T. Quinlan, who carried out a reconnaissance and began sampling the limestone. Reorganization of staff within the Bureau made it necessary to change this party, and L. C. Noakes, G. M. Burton, and M. A. Randal took over on the 28th April, began detailed investigations, and completed the work on 20th May. Detailed investigations were carried out in two stages; in the first, sufficient sampling was done across the strike of outcrops to provide a broad "chemical picture" of the belt which, together with a study of the stratigraphy, was designed to delineate areas where limestone of suitable grade occurred, and to indicate whether there were any geological factors controlling the chemical composition which could guide the search for suitable deposits. Work on these lines indicated that limestone of satisfactory grade existed in beds toward the top of the sequence exposed, and in the second stage of the investigation the area covered by these beds was mapped in detail by plane table.

The mapping and the results of analyses available at the time indicated one major and two smaller deposits, all of which offered economic quarrying from outcrop. Finally some additional check and bulk sampling was done.

At the outset channel samples were taken, but the method was changed to chip sampling which could be done in a fraction of the time. As a check on the results of this method, chip samples were taken by two independent samplers over a small outcrop previously channel sampled across the strike. The following analyses show that the two methods produced virtually the same result.

		SiO_2	R_2O_3	$CaCO_3$	$MgCO_3$
Channel Sample (across strike)		1.2	0.5	96.7	0.8
Chip Samples (taken over entire outcrop)	)A	1.4	1.1	95.4	1.6
	)B	1.5	0.8	95.5	1.9

The length of samples was controlled by lithology where changes were noted; otherwise lengths were kept approximately equal to avoid the necessity of weighting. In many places a straight arithmetical mean was used because chemical content, particularly silica, was fairly constant, and because, where deposits on the sample lines were not continuous, weighting was likely to introduce refinements not warranted by the exposures and the sampling method. Some additional details of sampling are given in the section on economic geology, and a complete list of chemical analyses is given in Appendix 3.

GENERAL GEOLOGY.

Little is known of the general geology of this district, and little can be added from this investigation because investigation of regional structure and stratigraphy were not essential to the problem.

The limestone at Flowery Gully forms part of a broad folded sequence of Lower Palaeozoic rocks which were subsequently covered by sub-horizontal Permian sediments, which blanket the older rocks south and west of Flowery Gully. The folded sequence exposed begins with sandstone, siltstone, and shaly beds - all of which are prominently gossanized in the only locality in which outcrops were found. These are overlain by the limestones of Flowery Gully, which are at least 1700 ft. thick, and these in turn are overlain by slate and sandstone to complete the local sequence. These beds have been folded together along a sub-meridional axis and dip fairly uniformly in an easterly direction at about 45 degrees as part of a broad fold. The limestone seems to be structurally conformable with the underlying sandy beds, a few hundred feet west of Quigley's Quarry (see Plate I), but the contact is not exposed. However, there is an erosional unconformity between the limestones and the overlying slate and sandstone. Some of the limestone beds have been truncated in a period of erosion which intervened before the deposition of the overlying beds. The folding of the sequence took place later still.

The grade of metamorphism within the sequence is generally low. Shale has been cleaved and converted to slate, particularly in beds above the limestone. Shearing is prominent in the limestones in places; dolomitic patches have, in most places, suffered recrystallization although the degree to which the limestone itself has been recrystallized is difficult to establish.

Previous workers (Nye, 1924; Hughes, 1950) noted that the limestone beds are not found north of the stream alluvium which forms the present northern limit of the belt, and an easterly trending transcurrent fault, which could displace the limestone, seemed a possibility. The occurrence of mineralized veins in the beds underlying the limestone, and the pronounced swing of bedding in the limestone toward the northeast at the northern end of the limestone belt, are consonant with the fault hypothesis. On the other hand, the erosional unconformity at the top of the limestone, with the truncation of beds, provides a possible explanation of the absence of limestone north of the alluvium without recourse to faulting.

The folded sequence is Lower Palaeozoic in age. The limestone beds, in which a few fossils have been found, are regarded as part of the Gordon Limestone of Upper Ordovician age* so that the sequence to the top of the limestone is probably Ordovician and the overlying slates possibly Silurian in age.

The Lower Palaeozoic rocks are covered west and south of Flowery Gully by unfolded sandstone, siltstone, claystone, and conglomerate. These were deposited on an uneven surface of the Lower Palaeozoic rocks: this unevenness explains the low elevation of the cover of conglomerate in the Winkleigh Valley, adjoining the southern end of Flowery Gully, at about the same elevation where limestone would outcrop had the surface of the unconformity beneath the younger sediments been approximately horizontal.

The thickness of these younger sediments was not measured, but the sequence within a mile west of Flowery Gully probably totals 180 ft. Fossils found in sandstone 400 feet south of Quigley's Quarry (see Plate 1) indicate a Permian age for these sediments (see Appendix 2).

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* Verbal communication from M. R. Banks; Geology Department, University of Tasmania.

THE LIMESTONE BELT.

GENERAL.

The limestones in Flowery Gully have been dissected to a maximum depth of 250 feet by the creek which, in most places, follows the meridional strike of the rocks (see Fig. 1). In its lower course, the stream channel disappears underground into the Flowery Gully Caves (see Fig. 3) and emerges approximately 1200 feet to the north below and sometimes into the present Sulzberger's Quarry. Underground drainage is effective along the entire length of the watercourse, which only functions as a surface stream in floods.

Limestone is found in scattered outcrops which total less than half the area underlain by limestone; thin to deep soil cover occupies the remainder. Most of the area underlain by limestone is improved pastoral land but at present none is used for agricultural purposes.

The positions of major outcrops of limestone are shown in Plate I, which is based on the plan prepared by Hughes (1950).

STRUCTURE AND LITHOLOGY.

Most of the limestone exposed conforms closely to an average strike of 150-160 degrees* and an average dip of 45 degrees to the east; but, toward the northern end of the belt the strike swings to 170-180 degrees although the average dip remains unchanged. Some cross-faulting may be involved in this change of strike, but no evidence was found in the outcrops.

The only fault of any consequence noted was a shear in the most westerly of Sulzberger's Quarries. The strike of this is close to that of the bedding and it dips east at 55 degrees, and lineations indicate that the major or last movement plunged gently northward. Some [illegible]ous ironstone occurs in the fault zone.

The evidence for a possible fault with major displacement toward the southern end of the limestone belt is discussed later.

In many places, the limestone shows the effect of shear in thin section and some outcrops show platy, light-coloured partings whose origin is not clear but is probably due to shearing.

The lithology remains remarkably constant throughout the crystalline limestone sequence which is at least 1600 feet thick. The limestones are fine-grained, and show no evidence of clastic origin either in hand specimen or in microslide. Sparse sand grains appear in thin sections but the evidence for chemical deposition appears very strong. As noted above, it is difficult to determine the degree to which recrystallization has taken place within the limestone. The only clastic sediment found within the limestone sequence was a 15-inch bed of dark shale found in the upper portion of Quigley's Quarry, about 200 feet stratigraphically above the base of the sequence (See Figure 5.)

In general, the limestone is massive or very coarsely bedded, and, in most places, the dip is readily determined. Bedded limestone, some very finely bedded, is prominent in Quigley's Quarries (see Fig. 2), toward the base of the sequence, and laminated beds appear at the upstream entrance to the Flowery Gully Caves.

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* All bearings magnetic.

Black chert nodules are found in the limestone in a number of places, but are apparently restricted to the middle portion of the sequence. Commonly they form slightly irregular lenses, 3-10 inches long and up to 6 inches in thickness, but they also appear as small, irregularly-shaped masses, doubtless formed by slump and roll of the plastic silica gel in deposition. In most occurrences, the cherts are elongated along bedding planes and serve as a guide to bedding (see Fig. 4).

Veins and lenses of calcite are common throughout the limestone, and range in width from mere stringers to veins and masses up to two feet across. In places, a minute ribbon of quartz occupies the central portion of a calcite vein.

The colour of the limestone, in most places, ranges from black to grey; only the uppermost beds are very light grey to off-white in colour. This variation in colour has some significance because the lightest coloured limestone has, invariably, a very low silica content (less than 1%), and, with one notable exception, dark limestone contains considerably more than 1%. W. B. Dallwitz, Senior Petrologist, Bureau of Mineral Resources, has confirmed that the dark colour is due to the presence of organic matter (see Appendix 1). The relationship between organic matter and silica content is discussed in the next section.

The presence of significant quantities of organic matter in the darker coloured limestone offers a simple explanation of the local lime-burners' preference for the darker stone and of their assertion that calcite from veins is not good material for lime burning. Even small quantities of organic matter help in the calcining of the stone because the ignition of the well distributed combustible organic matter assists the disintegration of the rock which produces more widespread heating of the limestone. The darker limestone also appears to be easier to mine and to split, again probably because of the organic content. On the other hand limestone which is very light in colour and calcite itself provide little or no dispersed combustible material to assist disintegration during heating and consequently the proportion of partially burned stone remaining in the kiln after firing is noticeably increased.

CHEMICAL CONSTITUTION.

The limestones are high-grade, in that the $CaCO_3$ content normally exceeds 94%, and content of iron and other impurities is very low, so that only silica and dolomite content and the possible role of organic matter need special comment.

Silica.

Silica is present throughout the limestone sequence, and ranges in amount from 0.1 to about 10% of the rock. It was important to determine the form of this silica. Early megascopic and microscopic examinations showed that the only obvious sources of silica were sporadic sand grains and rare ribbons of quartz noted in calcite veins, but these sources were totally inadequate to account for the amount of silica in the limestones. Furthermore, the very small clay content of the limestones, as indicated by low R_2O_3, showed that little of the silica present was in a combined form. The cherts are, of course, masses of silica within the limestone, but in most samples, cherts were carefully excluded. However, it was noted early in the investigation that limestone near a chert horizon, but with no trace of macroscopic chert, was invariably relatively high in silica.

Finally, W. B. Dallwitz examined the insoluble residues from a number of specimens (see Appendix 1) and discovered minute elongated rods and lenticules of quartz which appear to be the main source of the silica in the limestone.

The origin of these lenticular or rod-like masses is in doubt. Certainly, there are rare, very elongated rods which must be sponge spicules, and at least some of the shorter ones are probably broken spicules, although no distinctive cross-sections were found to confirm diagnosis.

All this material is now in the form of quartz, and not chalcedony. The presence of less regular, though elongated, particles suggests that some may be minute cherts, rolled and elongated after deposition and later crystallized to quartz.

The relationship between organic matter and silica content is logical whether the main source of silica is provided by sponge spicules or by chemical deposition. Sponges providing concentrations of spicules would also provide organic matter apart from that provided by other varieties of marine life. Krumbein and Garrels (1952) have shown the importance of the Eh factor (ratio of reducing to oxidising conditions) particularly in bottom waters, in the chemical deposition of silica. The deposition of silica is encouraged by a reducing environment. Hence when the reducing conditions of the bottom water probably were stronger because of a rise in the organic content of the limestone more silica was likely to have been deposited.

The reasons for the restriction of chert nodules to the middle portion of the sequence of Flowery Gully are not clear, but the concentration of silica in solution in the water could be the principal factor involved.

One widely held hypothesis (Twenhofel, 1932, p.541) suggests that major deposition of silica in limestone, as in chert horizons, requires the building up of silica concentration to a critical level, after which deposition may begin abruptly by electrolysis and continue while the concentration remains adequate.

On this basis concentrations of silica must have been brought up to critical level at the time of deposition of the middle portion of the Flowery Gully sequence, with resulting major deposition of silica and fall in concentration - a logical cause for the particularly low silica content of the upper beds of the sequence.

The silica in the limestone, apart from the visible cherts, is in the form of very finely divided quartz. For the most part, silica was deposited with the limestone (syngenetic), and there is little evidence of silica which has been re-distributed or introduced into the limestone from external sources.

Dolomite.

The mineral dolomite, which consists of 54% calcium carbonate and 46% magnesium carbonate, is found in most limestones, although generally in small amounts. Dolomite may be deposited direct from sea water but magnesium is generally introduced by solutions which replace calcite by dolomite soon after the limestone is deposited. Sea water provides the source of the magnesium. Limestones with a high content of dolomite are termed 'dolomitic' or magnesian limestones, and those with 45% magnesium carbonate or more are called 'dolomites'. However, for reasons of expediency, the term 'dolomite' in this report has been broadened to include all rock with a magnesium carbonate content higher than about 10% - rock which must obviously be rejected in mining.

The magnesium carbonate content of the limestones at Flowery Gully ranges from less than 1% to more than 30%. Magnesium carbonate occurs in minor quantities - up to 10% - throughout the limestone, but also occurs in much greater concentrations in restricted masses of dolomite which are found at many places within the limestone belt.

Unfortunately, it is not possible to discern small quantities of dolomite in limestone by megascopic examination or by acid treatment, so that the economic limits of deposits in which the magnesium carbonate content is below 10% can only be established by chemical analysis.

However, with a little experience, most of the high concentrations of 'dolomite' can readily be recognized. Most of these masses of 'dolomite' which may be 25 feet in width, and are commonly elongated in the direction of bedding, have a distinctive mottled brown appearance in outcrop. On closer inspection, tiny crystals of dolomite can be recognized, standing out in relief whereas the more calcareous material has been etched by weathering. Dilute hydrochloric acid, applied to a surface cleaned and smoothed with a file, dissolves the limestone and clearly outlines the less soluble grey or white rhombs of dolomite. The 'dolomite' is not so easy to recognize on fresh surfaces, such as clean quarry faces, where the distinctive brown mottling is missing, but in many places the fresh 'dolomite' has a dull grey colour, distinctive from that of the limestone, and close inspection and acid tests leave no doubt of its identity.

Many of these masses of 'dolomite' characteristically include an irregular network of small and large calcite veins and fragments of 'dolomite' surrounded by calcite; this commonly simulates a tectonic breccia but is in fact a reef breccia.

However, some 'dolomites', notably those in the main portion of Quigley's Quarry, look like fine-grained dark limestones and can only be recognized by their failure to react with acid.

Most of the 'dolomites', particularly in the middle and upper beds of the sequence, probably represented algal reefs - stromatoporoid bioherms - which built up from the sea floor. Those noted in the middle beds rarely extend along the strike for more than one to two hundred feet but the occurrence of a 'dolomite' bed extending for at least 1600 feet in the upper beds of the sequence seems to provide convincing proof of the origin of these masses. In this major reef, the bioherms have grown to a fairly uniform height of about 20 feet and now appear as a fairly regular 'bed' quite conformable with limestone above and below.

These reefs were originally built of calcium carbonate, but, in early stages of burial, the reefs, because of their high porosity compared to ordinary limestone, became traps for dolomitic solutions, and hence centres of high dolomite concentration.

In the upper beds, magnesian solutions have penetrated the limestone underlying the original reef to raise the average content of $MgCO_3$ to 4-5%, in contrast to an average content of only 2% in the limestone overlying the reef.

ENVIRONMENT AND SEQUENCE.

Environment.

The environment of deposition of the limestones can be fairly clearly deduced: it is marine. The occurrence of algal reefs, at least in the middle and upper portions of the sequence, indicates very shallow water, ~~probably little deeper~~ than 5 fathoms, because algal bioherms need light. Most of the sequence is, therefore, a shallow water deposit probably laid down on a shelf whose gradual subsidence allowed the accumulation of more than 2,000 feet of limestone.

Despite the shallow water, which normally presages that land is not far distant, there are no structures such as cross-bedding to provide evidence of strong currents. The almost complete lack of silt and sand and other clastic material within the sequence indicates that either adjacent land was of such low relief that only chemical weathering was active or that deposition of these limestones took place on a very extensive shelf or platform, portions of which were far removed from the influence of rivers and littoral conditions.

Further study of the environment would require regional data, but sufficient is known to indicate that the quiet, shallow-water conditions under which the limestones at Flowery Gully were deposited would provide a fairly consistent environment and an orderly sequence of sediments in which any significant changes should be readily followed along the strike. This is an important point in dealing with the sequence at Flowery Gully.

Sequence.

The only clue to structure in most places is the sequence within the limestone, and as there are no marked lithological changes to act as markers, the sequence may only be established on chemical grounds.

The subdivisions which the writers consider justified, on the work done, are shown in Plate 1. They are based mainly on silica content, and are termed 'silica zones'. They are not mappable rock units, although the indefinite boundaries of the zones do appear roughly to follow bedding, and, indeed, the zones themselves are believed to be the reflection of slight changes in environment, and are thus of stratigraphical value.

The complete sequence, toward the northern end of the limestone belt, is divided as follows:-

Lower Silica Zone - Approximately 900 feet of limestone - well bedded grey to black toward the base, with some shale, and slightly more massive grey limestone toward the top. The central portion of the zone does not crop out. 2-3% silica toward base, with beds of 1-2% silica in upper section. Magnesium content high in basal beds.

Chert Zone - Approximately 500 feet of limestone, mainly dark grey to black with lenses and patches of chert. Rock ranges from massive to well bedded. Silica content of limestone variable, but relatively high - normally above 2% and between 5 & 10% in vicinity of cherts.

Upper Silica Zone - Approximately 300 feet in most exposures, and consisting of (in ascending stratigraphical order) -

130 ft. dark, massive but low silica limestone (less than 1%), with magnesium carbonate content average about 5%.
25 ft. 'dolomite' bed (30% $MgCO_3$)
140± ft. very light coloured low silica limestone - mainly massive.

In the thickest section preserved (on the northern side of the cross-fault) an additional 300' of light-coloured limestone seems likely, increasing the complete section to almost 600'.

However, outcrops are very few in the area immediately north of the fault.

The total observed thickness of the limestone is approximately 1,700 feet, with a probable extension to 2,000 feet.

Faulting.

The interpretation of the sequence at the southern end of the limestone belt has important economic implications which fully justify the attempt to establish sequence and structure.

The sequence of chert zone and upper zone in the central and northern portion of the limestone belt cannot be followed into the outcrops in the southern end of the belt; hence either fault-displacement is involved or chemical changes in the limestone sequence are irregular, random features of no stratigraphical significance. The writers believe that the evidence is strongly in favour of the former alternative, and therefore have delineated the silica zones and the cross-fault which is implied by the offset zones. The fault is concealed by soil cover; it has not been proved in the field, and future workers can weigh the available evidence for themselves.

The probable fault has some topographic expression in the marked cleft or narrow valley at its south-western end, and in the apparent displacement of outcrops of limestone at its north-eastern extremity, but the main evidence of the displacement is as follows:-

1. The beds of the Upper Silica Zone, north of the fault - the dark limestone with low silica but appreciable magnesium content below the 'dolomite' bed, the 'dolomite' bed and the light-coloured low-silica limestone above - cannot be traced along the strike north of the fault, where outcrops contain chert and are similar to those in the Chert Zone north of the fault.

2. The pocket of grey, low-silica limestone in Deposit 2 (Plate 2) south of the fault, merges into high silica limestone with chert along the strike to the south, and is the counterpart of the main Sulzberger's Quarry in the Chert Zone north of the fault, where, in similar fashion, low to medium silica limestone grades into the chert-bearing rock north of R. Beams house (Plate 1).

3. A stratigraphical section through the limestone sequence south of the fault, with particular reference to the distribution of chert and silica values, gives the same sequence as that measured north of the fault with a 'chert zone' of approximately 500 feet in thickness.

4. The light-coloured limestone above the 'dolomite' bed in the Upper Zone is the most distinctive lithological type in the limestone sequence and the only exposures of limestone of this type south of the fault are found near Beams Bros.' No. 1 Quarry.

5. Rock type and silica content change markedly across the narrow valley at the south-western end of the fault (in samples 30, 31 and 50, Plate 1).

This evidence not only indicates that displacement has taken place but also implies considerable information on the fault itself. In the first place, displacement must have taken place before the sediments overlying the limestone were deposited because most of the beds of the Upper Zone on the up-throw (southern) side of the fault were removed before sedimentation was resumed. The faulting took place when the limestones were near-horizontal; the fault was normal, not transcurrent as appears now after subsequent folding of the limestone, with a throw of about 800 ft. on the northern side, by which the beds of the Upper Zone were faulted down and effectively preserved from erosion. The swing in the north-eastern boundary of the limestone north of the fault, between Sample 22 and 23, Plate 1, is the trace of an original fault scarp, some 200 feet high, which has been tilted by the subsequent folding of the complete local sequence.

ECONOMIC GEOLOGY.

DEPOSITS OF LOW SILICA LIMESTONE.

General.

The geological investigation of the limestone belt clearly indicated that the search for deposits of low-silica limestone should be concentrated on:-

(1) The Upper Zone
(2) Possible pockets of low-silica stone toward the base of the Chert Zone.

Additional guiding factors in the search were:-

(1) relief - to provide sufficient "backs" for economic quarrying

(2) outcrop - to indicate that the ratio of clay to solid rock would be reasonably low.

This last factor was of particular importance, because consistent production of limestone for the plant at Bell Bay had to begin well before the end of 1954. Ridges or hillocks, which have no outcrops, within a limestone belt should be avoided, if possible, because almost invariably zones or pockets of deep weathering will be found which increase the clay/rock ratio in quarrying and may make it difficult or impossible to adhere to a consistent production schedule.

As an example, the grassy hillside, 300 feet north-east of Deposit 3 (Plate 2), was "probed" at a number of points by pit and auger to a maximum depth of 11' to obtain geological information, but at no point was rock found.

Most of the area underlain by beds of the Upper Zone was mapped in detail by plane table, and mapping was extended to cover portion of the Chert Zone, south of the cross-fault, where a pocket of low-silica limestone had been indicated by reconnaissance sampling. This detailed work indicated the limits of a major and a minor deposit within the Upper Zone, and a minor one within the Chert Zone (see Plate 2).

None of the deposits was exhaustively sampled, because the samples taken, particularly in Deposits 1 and 3, showed remarkable consistency. For this reason, the grade of the deposits, as shown in the table of reserves, should be reliable, particularly as regards silica content. Possible variations in grade in Deposit 2 are noted below.

RESERVES OF LOW-SILICA LIMESTONE.
FLOWERY GULLY - TASMANIA.
Deposits 1, 2 & 3.

Deposit	Portion	Reserves of Limestone (long tons*)			Indicated Grade				Remarks
		Indicated	Inferred	Reduction Factor Used x	SiO_2	R_2O_3 ø	$CaCO_3$	$MgCO_3$	
					%	%	%	%	
	1(a)	330,000	-	35%	0.2 (Range) 0.1-0.2	0.5 0.3-0.8	97.0 94-98	2.0 1.3-3.9	Upper limestone beds (above the dolomite bed).
	1(b)	86,000	-	30%	0.4 (Range) 0.3-0.4	0.6 0.4-1.4	93.1 79-96	5.7 3.5-18.7	Lower limestone beds
1.	1(c)	-	46,000 14,000	40% 40%	Grade probably similar to that of (a) Grade probably similar to that of (b)				Upper limestone beds Lower limestone beds
	1(d)	262,000	-	35%	0.4 (Range)0.1-1.0	0.4 0.3-0.7	95.0 83-99	4.0/ 0.4-16.1	Both upper and lower beds. Dolomite bed and many dolomitic patches to be hand-sorted.
	1(e)	98,000 //	-	35%	0.4 (Range)0.1-1.0	0.4 0.3-0.7	95.0 83-99	4.0 0.4-16.1	Lower limestone beds - many dolomitic patches to be hand sorted.
					Inferred Grade.				
2.	-	120,000	-	30%	0.4 (Range)0.2-1.0	0.5 0.3-0.7	97.1 94-98	1.7 0.8-4.7	
3.	-	-	140,000	35%	0.5 (Range)0.2-0.7	0.5 0.4-0.7	96.7 96-98	1.8 1.1-2.3	Only three analyses.

* 14 cu.ft. limestone to the ton
x Reduction of volume of limestone to allow for soil, solution cavities, and hand-picked dolomite.
// Included in 1(d).
/ $MgCO_3$ content probably lower where limestone above dolomite bed included in run-of-quarry stone.
ø Al_2O_3, Fe_2O_3, etc.

Content of magnesium carbonate is less consistent and shows some irregularities in most places because it is the result of somewhat irregular replacement of calcite by dolomite.

The estimation of the tonnage of rock available is more difficult, and indeed can never be precise where limestone deposits are concerned.

The vulnerability of the rock to chemical attack by slightly acid ground water commonly leads to a very irregular surface of weathering beneath soil cover, and, at greater depth, produces solution cavities and caves which cannot be detected from the surface. The factor used in reducing the volume of any deposit to available rock material to allow for these contingencies must, to some extent, be an arbitrary one which is based on experience and the characteristics of the deposit concerned. In all deposits, the reserves estimated are <u>not</u> total reserves, but the quantity of stone which in our judgment could be economically quarried.

<u>Deposit 1</u> (Plate 2).

This is the major deposit, which should be capable of supplying Bell Bay for at least 20 years, even if only the most suitable stone is quarried. The deposit has been subdivided into 5 sections, mainly to indicate changes in the grade of the limestone. The main subdivision is provided by the central 'dolomite' bed and, for convenience, the limestones above are termed the "upper limestone beds" and those below the "lower limestone beds". In the southern portion of the deposit, where most of the reserves lie, limestone from both upper and lower beds could be quarried without removing the 'dolomite' bed, which would act as footwall to the quarry in the upper beds, and reserves have been calculated accordingly. The quarry limits, used in calculating reserves, are shown in the series of cross-sections on Plate 2, and all reduction factors used appear in the table of reserves.

The main difficulty in calculating reserves in portions of Deposit I was the indefinite location of the upper boundary of the limestone. As noted before, the contact between limestone and overlying slate is not conformable and is nowhere actually exposed. The top of the limestone approximates, therefore, to a land surface which existed before the slates were deposited; and this implies that the limestone boundary may be quite irregular in detail, and furthermore, that there could be caves or solution cavities developed in Lower Palaeozoic time and subsequently filled with shale. It is impossible to map this boundary without considerable costeaning, but the indefinite boundary shown seems a reasonable approximation.

It will be noted that an outcrop of limestone occurs outside the mapped boundary in the limits of section line J-K (Plate 2), indicating that the upper limestone beds in this area will probably be considerably thicker than allowed for, but the boundary was purposely restricted to the eastern edge of the main outcrops to provide conservative reserves in this area which may offset errors in the boundary to the immediate south. Deposit I is situated on a well-timbered hillside. Fern and shrub cover can be removed by burning, but 200-250 trees would need to be cleared if the entire deposit were worked.

<u>Deposit 1a.</u> This deposit includes over 300,000 tons of quarryable stone with very low silica content, and is recommended as the deposit in which quarrying should start. There are relatively few sizeable outcrops along the line of the deposit, but the consistency of both lithological type and chemical constitution

in the available outcrops leaves little doubt that grade will be consistent. No massive 'dolomite' was found above the main 'dolomite' bed, and as massive 'dolomite' tends to crop out more strongly than limestone, the absence of outcrop probably means that little massive 'dolomite may be expected.

The 'dolomite' bed will be the footwall of the quarry. The top of this bed is likely to be somewhat irregular, but detailed mapping on the surface indicates that in general it behaves as a bed within the limestone. Difficulties arising from the indefinitely mapped eastern boundary of the limestone have already been noted. This contact will not dip regularly to the east at 45°, as does bedding within the limestone, but errors from this irregularity are unlikely to affect estimation of reserves because it will not be practicable to quarry the limestone where it dips underneath the slate on the eastern side (see sections, Plate 2).

Quarrying of Deposit 1a could begin at either end. The northern end offers a slightly lower base level for a quarry floor, but the southern end offers the obvious advantage of a solid outcrop and promise of immediate production with a minimum of clay and overburden to be removed. Furthermore, outcrops at the southern end have been partly cleared of trees, of which there are about 100 on the deposit.

The level of the floor of the quarry at the southern end will be critical, and should be at 450 ft. on the datum used for the plane-tabling (Plate 2).

If the floor is higher than this level, reserves will be lost, and if below, dolomite may have to be removed to provide sufficient working width in the quarry.

The 450 ft. contour has been marked by 2 white pegs where the quarry should commence, and datum has been established at the gate on the western side of the road, 70 feet south of section line N-O (Plate 2). The level at the highest point of the southern gate post is 441.1 ft.

As quarrying progresses it is suggested that the actual limestone-slate contact be located by costeaning ahead of work, and a batter established in the soil and weathered slate east of the contact (see Sections, Plate 2), to enable the eastern wall of the quarry to be advanced as far as possible.

Deposit 1b. Reserves in this deposit could readily be quarried leaving the 'dolomite' bed standing on the hanging-wall side, but the average $MgCO_3$ content (5-6%) is unattractive. Samples indicate that the $MgCO_3$ content is less regular than in Deposit 1a.

If Deposit 1a and other deposits with lower $MgCO_3$ content are worked out, the reserves in 1b would, of course, be effectively lost unless tolerance for $MgCO_3$ were increased. If emphasis is put on the conservation of reserves, the only way to use Deposit 1b would be by mixing with other low-magnesium limestone. For instance, a mix of 2 parts of Deposit 1a and one part of Deposit 1b should provide an average of about 3-3.5% $MgCO_3$ content. A simple mix could be done by regulated truck loads to the hulk, but it is very doubtful whether the additional 5 years reserves so obtained would be worth the trouble involved.

Deposit 1c. Reserves are quoted as "inferred" in this section because no outcrops are visible and soil cover seems very thick.

It is possible that 40,000-50,000 tons of limestone from the upper limestone beds can be quarried here as a continuation of Deposit 1a, and some additional reserves, perhaps 20,000-30,000 tons, would be available by reversing the direction of work in Deposit 1a and quarrying south at the lower level provided by the topographical embayment in the area of 1c.

Deposits 1d and 1e. In this area, toward the northern limit of Deposit 1, the upper limestone beds are probably too thin to be quarried by themselves. Furthermore, caves are known to exist toward the southern limit of these beds in Deposit 1d. Hence, there are two alternatives - either the whole upper zone, east of the road, is quarried and the dolomite bed rejected by hand picking (1d), or the lower limestone beds are quarried alone (1e).

$MgCO_3$ content is likely to be more variable than in deposit 1a and a probable average is about 4%. The overall reserves and tolerance for $MgCO_3$ will dictate whether any portion of Deposit 1d is quarried, but the hand-sorting of the whole dolomite bed should be avoided if possible. The quarrying of Deposit 1e, nearly 100,000 tons, is a better proposition and the grade is quite attractive, particularly toward the southern end; but reserves have been calculated on a basis of a quarry extending to the present road (which could be fenced) and working below road level (see Sections, Plate 2). Any local government regulations against these practices will greatly reduce reserves or involve considerable expense in re-locating the road.

It is unlikely that Deposit 1e could be extended much to the north where it would impinge on the chert zone.

Deposit 2.

The No. 2 Deposit is a small pocket of low-silica limestone lying in the Chert Zone about 1,200 feet south of the southern limit of the No. 1. Deposit. It is 200 feet west of the road and access is gained by a short bush track. The deposit bears a medium to heavy cover of timber.

The reduced level of the quarry floor would be 560 feet and excavation would begin in the quarry at the north-eastern corner; the existing floor of this quarry is slightly above 560 feet. The reserves of No 2 Deposit quarry will be 120,000 tons.

The inferred grade of limestone is 0.4 percent silica, 1.7 percent $MgCO_3$ and 97.1 percent $CaCO_3$. In view of the abrupt variations which occur in the silica content in this zone, as exemplified by analyses of nearby limestone, the silica figure of this grade should be taken as a guide to expected quality rather than a ntee, for it is just possible that patches higher in silica may be encountered at depth. The same remark applies to the percentage of $MgCO_3$: in this particular area dolomitization has taken place in irregular patches rather than along a distinct bed and although the main surface areas of 'dolomite' have been excluded from the quarry zone some patches may be encountered at depth.

Although this area is not as attractive as No. 1 Deposit and does not offer the same quarantee of continued quality, it provides a valuable quantity of good limestone, and no difficulty should be experienced if quarrying is begun near the existing north-eastern quarry, where both the quarry face and nearby outcrop samples have shown low-silica limestone and where there is little clay overburden. Regular sampling and analyses should be carried out, particularly if the presence of black chert nodules or large dolomite patches is detected. This will permit the early determination of poor limestone at depth and permit a revision of quarrying plans and a reassessment of reserves.

Deposit 3.

The third deposit immediately adjoins Beams Bros' No. 1 Quarry and lies at the extreme southern end of the area surveyed, (Plate 2). The existing quarry track provides access to the Beaconsfield road.

This pocket of Upper Zone limestone, fortuitously preserved from erosion, becomes unworkable to the north owing to thinning and alluvial cover. Its eastern boundary is defined by its junction with the overlying disconformable slate and quartzites and its western boundary is the passage into the Chert Zone, with a consequent rise in silica content of the limestone. To the south, the present limit is marked by its disappearance beneath the overlying Permian sediments and the branch road.

The existing quarry has worked limestone from the Chert Zone, and it would have to be extended to the east and south-east to yield low silica stone. To obtain the full benefit of the reserves available it would be necessary to work from the 520-foot level, which corresponds to the level of the entrance of the present quarry. The present easterly quarry face provides a suitable entry to the high quality limestone. Part of the eastern face exposed in April 1954 was made up of the high silica zone of the Chert Zone and it would be necessary to break through this before reaching the low-silica beds above and to the east (Section XY, Plate 2).

Total inferred reserves have been estimated at 140,000 tons and the inferred quality based on three samples, which were reasonably consistent, was very good: the average yielded a content of 0.5 percent silica, 1.8 percent $MgCO_3$ and 96.7 percent $CaCO_3$.

Additional Deposits of Low-Silica Limestone

The search for additional reserves should be concentrated on the Upper Zone. There are two areas in which investigations is warranted. The most attractive one is the southern continuation of Deposit 3, where the beds of the Upper Zone appear to be thickening in a southerly direction. The limestones pass under a cover of Permian sandstone and conglomerate immediately north of the eastern branch road, south of Deposit 3 (Plate 1), but the sink holes in the conglomerate immediately south of this road and to the east of the Winkleigh Road indicate that limestone is underfoot, and preliminary evidence suggests a thin conglomerate cover.

Provided the beds of the Upper Zone, preserved below the unconformable contact of limestone with slate, do not decrease in thickness, this area offers a promise of great reserves, although conglomerate cover would have to be removed.

The second area lies between Deposit 1 and the cross-fault. Some low-silica stone will be available east of the road but present indications are that ratio of clay and soil to rock would be high.

Better conditions exist west of the road, in the triangle between road, fault, and boundary of the Chert Zone. Even allowing 50% wastage, reserves of the order of 200,000 tons might be quarried here. There are, however, foreseeable difficulties. The area has no outcrop and much clay overburden will probably have to be removed. If the dolomite bed continues along the strike, it would have to be hand-sorted, and most of the reserves would be provided by the lower limestone beds, and may well be relatively high in magnesium carbonate. However, the 'dolomite' reef might lens out, and lead to a decrease in $MgCO_3$ content of the lower limestone beds. For this reason, a shaft to test the lower beds in this area would be warranted as part of any programme to establish additional reserves, although the southern extension of Deposit 3 offers by far the better promise.

Detection of Dolomite, and Quarry Sampling.

Attempts have been made to provide a chemical solution which could be used by a quarry foreman in the detection of 'dolomite', but so far, no real improvement on weak hydrochloric acid (N.HCl) has been found. Lemberg's solution, which often acts as suitable dye test, proved unsatisfactory when tested on the Flowery Gully samples in the laboratory but this may be partly due to the fact that extract of logwood, used in its preparation, was not available, and an extract of dubious properties was prepared after much difficulty in the laboratory.

Patches of dolomite can be clearly discerned in outcrop because of brown mottling, and it is likely that most patches in fresh rock will be apparent from the grey metallic hue and the presence of etched rhombs of dolomite.

Further indication is provided by treating the rock with weak hydrochloric acid, applied on a surface smoothed by a file. In this treatment, limestone shows uniform effervescence and dolomite shows markedly less effervescence; a pitted surface is produced on which crystals of the less soluble dolomite stand out in relief.

In establishing the quarry at the Southern end of Deposit 1a, the delineation of the 'dolomite' footwall will provide some experience for quarrymen which should enable them to reject any pocket of 'dolomite' found in the limestone above the footwall. The boundary of the 'dolomite' bed will probably be slightly irregular, and some streaks or lenses of brown or grey 'dolomite' may appear in the limestone near the contact. These may produce a zone of limestone of higher $MgCO_3$ content near the contact, but the width is not likely to be sufficient to affect significantly the overall grade of run-of-quarry stone.

Sampling should provide no difficulties in Deposit 1a, where outcrop samples indicate a fairly uniform grade. Chip samples across the strike should be taken regularly while the quarry is being established as a check on grade, and limestone near the contact with the 'dolomite' should be given special attention. Once the quarry is established, routine face-sampling, possibly after each major blasting, should be sufficient, although any apparent change in lithological type should be checked by analysis.

Conclusions and recommendations.

The investigation showed that there are reserves of low silica limestone at Flowery Gully sufficient to supply the Bell Bay plant, at present capacity, for 50 years.

However, some of these reserves are relatively high in $MgCO_3$ and others would involve some difficulty in quarrying. If the Commission restricts itself to the most suitable deposits (1a, 2 and 3) it has reserves totalling 620,000 tons, of which 330,000 tons are provided by the major deposit - 1a.

It is recommended that tenure should be secured over the whole of Deposit 1 and production should begin at the southern end of Deposit 1a. This deposit should be worked consistently but tenure should also be secured to Deposit 2 for the following reasons -

(1) An additional face capable of providing an emergency supply of suitable limestone is advisable because the main quarry in Deposit 1a will be narrow and a landslide or an unexpected pocket of clay could easily hold up production and embarrass the plant. If only small stocks are to be held at Bell Bay, a second face, such as that provided at Deposit 2, would be warranted.

(2) Although Deposit 2 does not provide the same promise of uniform grade as Deposit 1a, the stone at outcrop has a low silica content, small quarry faces are already present and outcrop is extensive. Therefore, this stone should not be wasted.

No immediate development is recommended at Deposit 3, but the possibility of reserves in the southerly continuation warrants securing tenure if the Commission, at any time, considers that any rival interest may become interested in these reserves.

When the Commission decides that insufficient reserves of low-silica limestone are in sight, prospecting with geological control, should be carried out in the areas, mentioned above, situated south of deposits 1 and 3.

The difficulties which may arise in quarrying have been stressed and the importance of obtaining a competent quarry foreman is imp rtant. The difference between a good and a mediocre quarry master is likely to be reflected in the quality of limestone, continuity of production, and conservation of reserves.

LIMESTONE FOR MANUFACTURE OF PORTLAND CEMENT.

The suitability of these limestones for use in the manufacture of cement has already been noted by Nye (1924) and others; but the information on grade, shown on Plate 1, provides some more detailed information.

In general, the raw mix for the manufacture of Portland cement should contain about 75% calcium carbonate, about 20% silica, alumina and iron oxide and not more than 5% magnesia (MgO) and alkalies. Limestone from Flowery Gully would, of course, have to be mixed with shale (which could be obtained locally (Nye 1924)) to provide the necessary alumina and iron oxide and some of the silica.

The constituents of the limestone at Flowery Gully which need consideration are silica and magnesium carbonate. Areas in which the limestone contains chert nodules should be avoided for a number of reasons. Some of the cherts could be hand-sorted; but even so, the ground product is likely to show irregularities in silica content, and wear on crushing machinery would be considerable. Moreover, the silica content would be high and would consist mainly of uncombined quartz and chalcedony.

Magnesia (MgO) is probably the most common objectionable constituent of limestone for Portland Cemnet manufacture because it tends to remain inert and to decrease the strength of the cement. Most standard specifications permit only 5% in the finished cement, so that 5% MgO, or about 10% $MgCO_3$, is the maximum tolerance in limestone for cement. Actually, the magnesia content should be well below the maximum figure.

These considerations indicate that limestones suitable for use in manufacturing Portland Cement are mainly found in the Upper Zone (excluding the 'dolomite' bed), in the upper portion of the Lower Zone, and in places in the Chert Zone. The most suitable areas of outcrop may clearly be seen by reference to Plate 1 - taking most suitable areas as those without cherts and with less than 6% magnesium carbonate.

LIMESTONE FOR OTHER INDUSTRIAL USES.

Besides the two uses already discussed, limestone is used widely in road building and as aggregate in concrete construction; it is used also in the manufacture of paper, wool rock, and of cements other than Portland; and it is calcined for the production of quicklime, which is used extensively in mortar, in tanning, and as a soil conditioner in agriculture.

For road construction the Flowery Gully limestone offers an excellent source of metal. All zones of the deposit are suitable. The heavily dolomitized areas within the zones are likely to be slightly inferior to the purer limestones because of lower solubility and consequent binding power, and because the increased hardness may make crushing more difficult.

No information has been obtained on the bonding ability of Flowery Gully limestone and bitumen and the limestone should not be used for bitumen surfacing until this has been tested; normally limestones combine well with bitumen and resist water but abnormal stripping limestones have been recorded in other places and testing safeguards must be taken.

The lighter coloured but non-dolomitic limestones are likely to be most suitable for use as aggregate in cement construction because it is known that where the lightness of colour is not due to dolomitization it is an indicator of the quantity of carbonaceous material present. This carbonaceous matter can produce acids which are known to attack and weaken the aggregate. Chert nodules, because of their chalcedony, should not be used with high-alkali cements, [illegible] the durability of cherts is always questionable in cement aggregates.

All zones of the limestone appear to contain limestone suitable for the manufacture of wool rock. It would be necessary, however, to add sufficient siliceous or argillaceous rock to reduce the content of calcium and magnesium carbonate to between 40% and 65%. Uniformity of the source materials is a desirable feature for such composite wool rock, but little difficulty should be encountered in finding uniform limestone in all zones of the Flowery Gully limestones. Data are not available on the effect of variation in the ratio of magnesium to calcium, but if the variation is undesirable the difficulty could be overcome by avoiding the strongly dolomitized zones.

Limestone is used widely in the several paper manufacturing processes. It is known that in some of the processes the presence of large quantities of magnesium carbonate is undesirable whereas in others it is quite permissible. Hence the suitability of the various zones will be governed by the particular requirements of the manufacturer and can be selected readily after reference to the plans and text of this record. It should be noted, however, that the black cherts of the Chert Zone may cause excess wear in the crushers and yield a product of inferior consistency. The presence of large quantities of silica in the zone may also be undesirable.

As has been mentioned earlier in the text the limestone has been used extensively already in the preparation of quicklime for mortar and agricultural purposes. Preference is shown for the darker stone by some users and a possible explanation of this has also been given earlier. The quicklime prepared for these purposes would also be useful as a depilatory in tanning.

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APPENDIX I.

PETROLOGICAL NOTE.

by

W. B. Dallwitz

Senior Petrologist

The scope of this brief report is largely confined to a discussion on the form of the silica, apart from that present as macroscopically visible chert nodules and lenses.

Any petrographic notes on points not directly connected with the subject of silica are added only incidentally; no attempt has been made to discuss the petrography of any one specimen or any group of specimens completely.

The report is based on the examination of specimens representing the various types of limestone in the Flowery Gully deposits.

Coarse chips of several specimens of limestone were treated with hydrochloric acid until effervescence had ceased. The insoluble portions were ignited to remove black carbonaceous material which was present in appreciable quantity in most specimens; the residues were examined microscopically and tested chemically, and found to consist of the following materials:

1. Roughly lenticular aggregates of irregular, interlocking, cigar-shaped pieces of quartz. These aggregates are up to 0.2mm. long and 0.05 to 0.1 mm thick.

2. Cigar-shaped pieces of quartz measuring about 0.2 by 0.04 to 0.08mm.

3. A very finely-divided clay mineral in which the presence of aluminium was confirmed by chemical tests. This mineral accounts for some of the silica in the limestones.

4. Irregular grains of quartz measuring from 0.02 to 0.04 mm

5. Minute grains of iron oxide.

6. Rods of quartz measuring from 0.25 to 0.35 mm. in length, and from 0.02 to 0.04 mm. in thickness. These may be sponge spicules, originally consisting of amorphous silica, which has now been converted to quartz. Several of the rods are splayed outwards at one end.

7. A single Y-shaped piece of quartz, with the two arms corresponding to the upward-pointing parts of the letter very much truncated, was noted. This may also represent a sponge spicule.

The types of quartz represented by 1 and 2 above are probably original chert or opaline silica, precipitated in the same way as the large chert nodules, and now converted to quartz. Some of the cigar-shaped pieces of quartz may represent sponge spicules broken during deposition of the limestone, or during shearing movements or both. It is impossible to state whether the irregular grains of quartz, referred to under 4 above, are of detrital origin or whether they represent precipitated opaline or cryptocrystalline silica subsequently converted to quartz.

In these limestones, therefore, microscopic silica is present both in the form of quartz, and as a component of clay.

In secondary calcite veins quartz occurs in coarser form than in the body of the limestone. Some noted in thin section measured up to 2 mm. in grainsize, but in the field considerably larger grains and aggregates of grains were observed.

Most of the limestones examined in thin sections show strong evidence of shearing, and field geologists believe that the shear-planes coincide with the bedding-planes. Recrystallized calcite occurs as lenses measuring up to 1 mm. in length with their long axes lying parallel to the shear-planes. The average grain-size of the limestone in which these lenticular masses are embedded is of the order of 0.02 mm., but some of the uniformly recrystallized light grey limestones have an average grainsize of 0.1 to 0.2 mm.

Dolomite, which is easily observed on etched surfaces of the limestones, lies along the bedding, or shear, planes as lenticular aggregates of rhombs. These rhombs measure about 0.5 by 0.4 mm.

Organic matter is visible in thin section as thin, dark, irregular, discontinuous streaks lying approximately along the bedding, or shear, planes, and is much less abundant in the light grey than in the dark grey limestones. When the limestones are treated with acid the carbonaceous material tends to float on the surface of the solution as a black scum; it is readily oxidized, during ignition of the insoluble residues.

Limonite was noted in several specimens. It is probably derived from pyrite during weathering. Pyrite is present as cubes and grains in two of the ten specimens examined, and is most abundant in one of those containing portion of a large chert nodule. This nodule was found to contain numerous calcite granules, particularly near its margin, and even a few dolomite rhombs, showing that carbonate was precipitated concomitantly with the silica, Subsequent fracturing of the nodule, either during dehydration at the time of diagenesis, or as a result of later shearing, has allowed the introduction of calcite as thin veins. Numerous minute grains of pyrite are distributed throughout the chert nodule. The presence of pyrite within the nodule and also in the surrounding limestone indicates that the silica was deposited in a reducing environment.

APPENDIX 2.

PALAEONTOLOGICAL NOTES.

by

G. A. THOMAS

Geologist

The fossils collected by G.M. Burton and T. Quinlan 400 feet south of Quigleys Quarry have been examined; three recognisable species are present. They are:

Trigonetreta cf. *stokesi* Koenig

Grantonia cf. *hobartensis* Brown

Eurydesma sp.

The specimens are all moulds in pebbly sandstone, some external and some internal, and for the most part not very well preserved. *Trigonetreta* and *Grantonia* have a long range in the Permian of Tasmania. The two brachiopod species present are smaller than the types of *Trigonetreta stokesi* and *Grantonia hobartensis*, respectively, both of which come from the Berriedale Limestone near Hobart. The size difference probably reflects on environmental difference. Both species probably range throughout the Tasmanian Permian. *Eurydesma* is a characteristic Permian genus. The age of the deposits is therefore established as Permian.

(G. A. Thomas)
Geologist.

APPENDIX 3.

List of Analyses.

The samples submitted by the Geological Party were analysed by officers of the A.A.P.C. in the Commission's Bell Bay laboratory under the direction of chemists R.A. Dunt & F.K.Mackenzie.

ANALYSES OF LIMESTONE

FLOWERY GULLY, TAS.

Laboratory No.	SiO_2	R_2O_3	$CaCO_3$	$MgCO_3$
9021	0.9	0.9	94.2	3.4
9022	0.5	0.6	95.8	2.7
9023	0.5	0.6	94.4	4.3
9024	0.4	0.5	94.3	4.4
9025	0.6	0.6	97.1	1.2
9026	0.4	0.5	97.7	0.8
9027	0.5	0.7	95.2	3.6
9028	0.4	0.5	98.0	0.8
9029	0.3	0.5	94.8	4.3
9030	0.3	0.5	98.0	1.0
9031	0.2	0.7	87.5	11.9
9032	0.6	0.5	94.3	4.7
9033	0.4	0.3	97.0	0.8
9034	0.6	0.4	97.0	0.8
9035	1.3	1.2	95.0	2.6
9036	3.8	1.4	90.0	3.4
9037	3.6	1.6	84.0	10.0
9038	3.6	1.0	84.0	9.8
9039	14.0	3.7	79.0	1.4
9040	1.5	0.5	95.0	0.8
9041	2.9	0.9	91.0	3.6
9042	1.3	0.5	90.0	5.9
9043	1.5	1.3	79.0	18.2
9044	2.0	1.6	75.0	20.7
9045	1.3	0.6	95.6	2.0
9046	1.0	0.6	97.1	1.4
9047	2.5	0.7	93.5	3.3
9048	2.4	0.9	93.7	2.8
9049	1.6	0.8	95.2	2.2
9050	2.5	0.8	94.8	1.9
9051	2.6	1.1	92.6	2.6
9052	1.4	0.8	93.7	2.9

Laboratory No.	SiO_2	R_2O_3	$CaCO_3$	$MgCO_3$
9053	2.3	0.9	94.0	1.8
9054	1.8	0.9	94.6	1.4
9055	3.9	1.3	90.8	2.8
9056	1.4	0.8	94.0	2.9
9058	43.2	5.7(Fe); 5.8(Al)	22.1 CaO	2.2 Mgo (21% ignition loss)
9059	1.6	0.5	86.2	10.3
9060	0.8	0.7	94.9	2.3
9061	3.7	0.9	89.2	5.6
9062	9.5	0.6	82.6	6.2
9063	3.4	0.6	88.6	6.4
9064	4.4	1.0	81.4	12.4
9065	19.0	1.3	77.3	1.7
9065	19.0	1.3	77.3	1.7
9066	20.4	1.2	75.2	3.1
9067	4.0	0.8	91.0	3.4
9068	5.2	1.0	88.6	4.6
9069	4.0	0.8	92.3	2.1
9070	2.8	0.7	94.3	1.4
9071	3.6	3.7	94.2	1.0
9072	3.3	0.7	94.5	1.1
9073	3.1	0.6	93.8	1.9
9074	3.1	0.6	94.1	1.6
9075	5.6	0.7	91.2	2.4
9076	7.2	0.8	89.2	2.7
9077	4.1	0.8	93.1	1.5
9078	9.3	0.8	88.6	0.9
9079	2.3	0.7	94.2	2.1
9080	0.5	1.3	94.7	2.2
9081	0.8	0.5	89.2	10.0
9082	1.9	0.6	61.5	35.5
9083	3.2	0.8	93.8	1.8
9084	6.7	0.7	90.4	2.1
9086	7.8	0.9	87.8	3.3

Laboratory No.	SiO_2.	R_2O_3	$CaCO_3$	$MgCO_3$
9087	3.5	0.9	91.6	3.5
9088	8.7	1.0	84.5	5.6
9089	6.6	0.7	88.4	3.9
9090	3.0	2.1	57.7	36.9
9091	1.5	0.9	95.8	1.6
9092	1.4	0.7	96.3	1.0
9093	1.6	0.9	95.7	1.2
9094	1.7	0.9	96.2	0.9
9095	1.6	0.8	96.4	1.0
9096	2.6	0.9	94.5	1.0
9097	2.7	0.9	94.7	0.9
9098	1.8	0.9	95.3	1.1
9099	1.6	0.7	95.9	1.2
9100	1.9	0.7	95.2	1.4
9101	2.1	0.7	95.7	0.9
9102	4.6	0.9	90.2	3.8
9103	4.1	0.7	93.0	1.2
9104	4.1	0.8	93.0	1.4
9105	2.2	0.8	95.3	1.2
9106	2.9	0.9	91.8	3.6
9107	3.7	0.9	88.6	6.1
9108	2.4	0.9	95.2	1.2
9109	2.8	0.9	95.4	0.9
9110	19.6	1.1	73.6	5.8
9111	2.3	1.0	95.5	1.0
9112	2.3	0.9	95.7	1.0
9113	2.7	0.9	95.2	1.0
9114	2.2	0.7	95.6	1.2
9115	2.4	0.9	95.1	1.2
9116	2.2	0.8	95.4	1.2
9117	1.7	0.7	95.8	1.4
9118	2.5	0.9	94.6	1.8
9119	3.8	1.1	93.5	1.3

Laboratory No.	SiO_2	R_2O_3	$CaCO_3$	$MgCO_3$
9120	9.4	2.1	87.7	0.9
9121	10.0	1.4	88.0	1.0
9122	5.1	0.8	92.3	1.4
9123	4.4	1.1	92.6	1.4
9124	4.9	1.2	92.3	1.5
9125	4.7	1.0	93.0	1.1
9126	4.9	1.4	92.4	1.4
9127	4.6	1.1	92.7	1.3
9128	4.0	1.0	93.1	1.5
9129	3.8	1.1	92.9	1.4
9130	5.0	1.4	91.2	1.6
9131	5.3	1.2	90.9	1.6
9132	5.0	1.0	92.2	1.6
9133	6.1	1.0	91.1	2.0
9134	6.6	1.1	89.2	2.8
9135	4.1	1.1	92.1	2.4
9136	2.9	0.9	94.4	1.7
9137	3.1	2.8	60.4	33.5
9138	3.2	1.0	91.6	3.2
9139	3.6	0.9	93.0	1.3
9140	2.1	0.7	95.3	0.8
9141	3.7	0.8	93.9	0.7
9142	1.8	1.1	95.2	1.1
9143	3.7	0.7	93.8	0.9
9144	3.1	0.5	94.4	1.2
9145	0.6	0.7	97.2	0.8
9146	1.6	0.4	96.5	0.8
9147	1.1	0.4	96.7	0.9
9148	1.4	0.4	96.5	0.8
9149	4.0	0.7	92.9	1.4
9150	3.9	0.9	94.1	1.0
9151	3.2	1.0	94.7	1.0
9152	3.0	0.9	95.1	0.9
9153	1.3	0.7	93.3	4.5

Laboratory No.	SiO_2	R_2O_3	$CaCO_3$	$MgCO_3$
9154	5.1	1.2	90.5	2.7
9155	7.4	1.5	84.3	6.2
9156	8.5	1.0	85.5	4.4
9157	0.6	1.5	79.1	18.1
9158	0.5	1.1	85.4	12.1
9159	0.6	0.7	88.3	10.4
9160	0.3	0.4	94.2	4.7
9161	0.2	0.3	96.4	2.8
9162	0.6	0.8	93.5	4.9
9163	0.4	0.5	97.5	1.3
9164	0.4	0.5	96.9	1.8
9165	0.5	0.6	97.0	1.4
9166	3.9	0.8	94.0	1.1
9167	1.4	1.1	95.4	1.6
9168	1.5	0.8	95.5	1.9
9169	0.2	0.8	96.6	2.0
9170	1.0	0.7	96.4	1.6
9171	7.5	1.0	83.5	7.8
9172	1.0	0.4	97.1	0.8
9173	4.0	0.6	91.4	3.0
9174	0.9	0.4	97.4	0.8
9175	0.3	0.4	97.3	0.9
9176	0.8	0.7	92.3	5.2
9177	3.7	0.7	88.8	5.7
9178	0.7	0.7	95.9	1.9
9179	2.2	0.8	94.6	1.4
9180	0.4	0.5	96.0	2.1
9181	6.9	0.9	88.0	3.4
9182	11.1	1.5	85.1	1.4
9183	2.5	0.9	93.2	2.5
9184	0.1	0.3	98.2	1.3
9185	0.1	0.3	98.0	1.3
9186	0.4	0.6	91.7	7.1

Laboratory No.	SiO_2	R_2O_3	$CaCO_3$	$MgCO_3$
9187	0.4	1.4	79.4	18.7
9188	1.6	1.2	81.1	16.0
9189	2.6	0.9	94.8	1.2
9190	3.8	0.7	93.5	1.1
9191	1.3	0.5	93.9	3.7
9192	1.6	0.5	95.1	2.3
9193	1.6	0.6	94.9	2.6
9194	0.3	0.7	93.0	5.7
9195	0.3	1.0	91.6	6.7
9196	1.1	0.5	94.8	3.3
9197	2.0	0.6	94.0	2.9
9198	1.8	0.6	95.5	1.5
9199	2.4	0.8	94.3	1.9
9200	1.4	0.6	95.4	2.1
9201	1.5	0.8	93.9	3.2
9202	3.0	1.0	93.8	1.4
9203	2.6	0.9	94.2	1.6
9204	2.4	1.1	90.9	4.6
9205	3.8	1.0	91.9	2.2
9206	4.5	1.7	73.4	20.2
9207	11.1	1.0	84.2	3.1
9208	1.9	1.2	86.5	9.6
9209	1.1	0.9	88.3	9.1
9210	0.5	0.5	97.0	1.9
9211	0.3	0.4	94.2	5.1
9212	0.3	0.3	96.1	3.1
9213	0.3	0.4	95.6	3.5
9214	0.3	0.5	94.9	4.1
9215	0.2	2.6	66.7	30.1
9216	0.2	0.3	94.4	3.9
9217	0.1	0.3	97.3	1.5
9218	0.4	0.6	91.5	6.7
9219	0.2	0.2	97.7	1.4

Laboratory No.	SiO_2	R_2O_3	$CaCO_3$	$MgCO_3$
9220	1.4	0.8	93.7	4.0
9221	0.5	0.5	94.0	4.9
9222	0.3	0.7	83.0	16.1
9223	0.1	0.3	99.2	0.4
9237	0.2	0.5	98.0	1.1
9238	0.3	0.5	97.8	1.3
9239	0.3	0.5	96.9	2.2
9240	0.5	0.5	97.5	1.3
9241	1.2	0.7	96.0	1.7
9242	0.6	0.5	96.4	2.3
9243	8.3	0.8	84.5	6.3
9244	3.6	0.5	94.2	1.2
9245	1.6	0.5	96.6	1.0
9246	0.5	0.5	95.8	2.5
9247	1.0	0.7	96.2	1.8
9248	3.4	0.9	87.4	8.3
9249	0.6	0.5	97.8	1.1
9250	0.3	0.5	97.7	1.1
9250	0.3	0.4	97.4	1.8
9252	0.6	0.6	92.0	6.8
9296	0.3	0.7	97.1	1.7
9297	0.3	0.6	96.2	2.6
9298	0.4	0.8	92.4	6.1
9299	0.3	0.8	90.0	8.8
9303	0.4	0.9	86.0	12.6
9304	0.3	0.6	93.8	5.4
9305	0.5	0.5	97.3	1.4
9306	0.2	0.4	97.9	1.1
9307	1.5	0.7	96.2	1.3
9308	1.8	0.8	95.8	1.3

Fig. 1 - General view looking south along Chert Zone from Section AB, Plate 1. Upper Zone (low silica) is the heavily timbered area on the extreme left.

Fig. 2 - Lower Quigley's Quarry - limestone of Lower Zone dipping to the east.

Fig. 3 - Sink hole in Chert Zone near R. Beam's house. Drainage enters Flowery Gully Caves at this point.

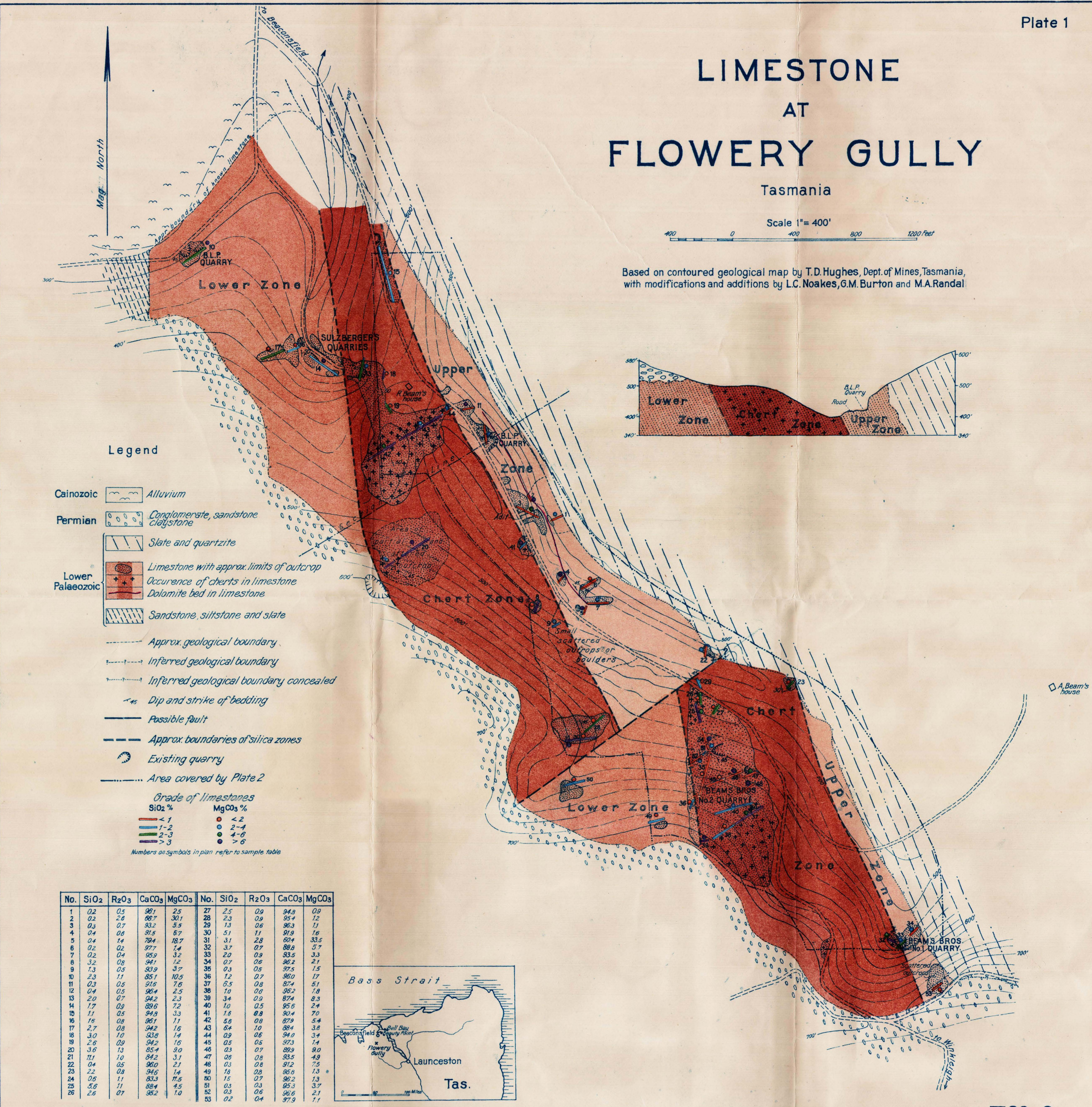
Fig. 4 - Bedded chert nodules in Chert Zone in Beams' No. 1 Quarry.

Fig. 5 - Upper Quigley's Quarry - interbedded limestone and shale.

Plate 1

LIMESTONE AT FLOWERY GULLY

Tasmania

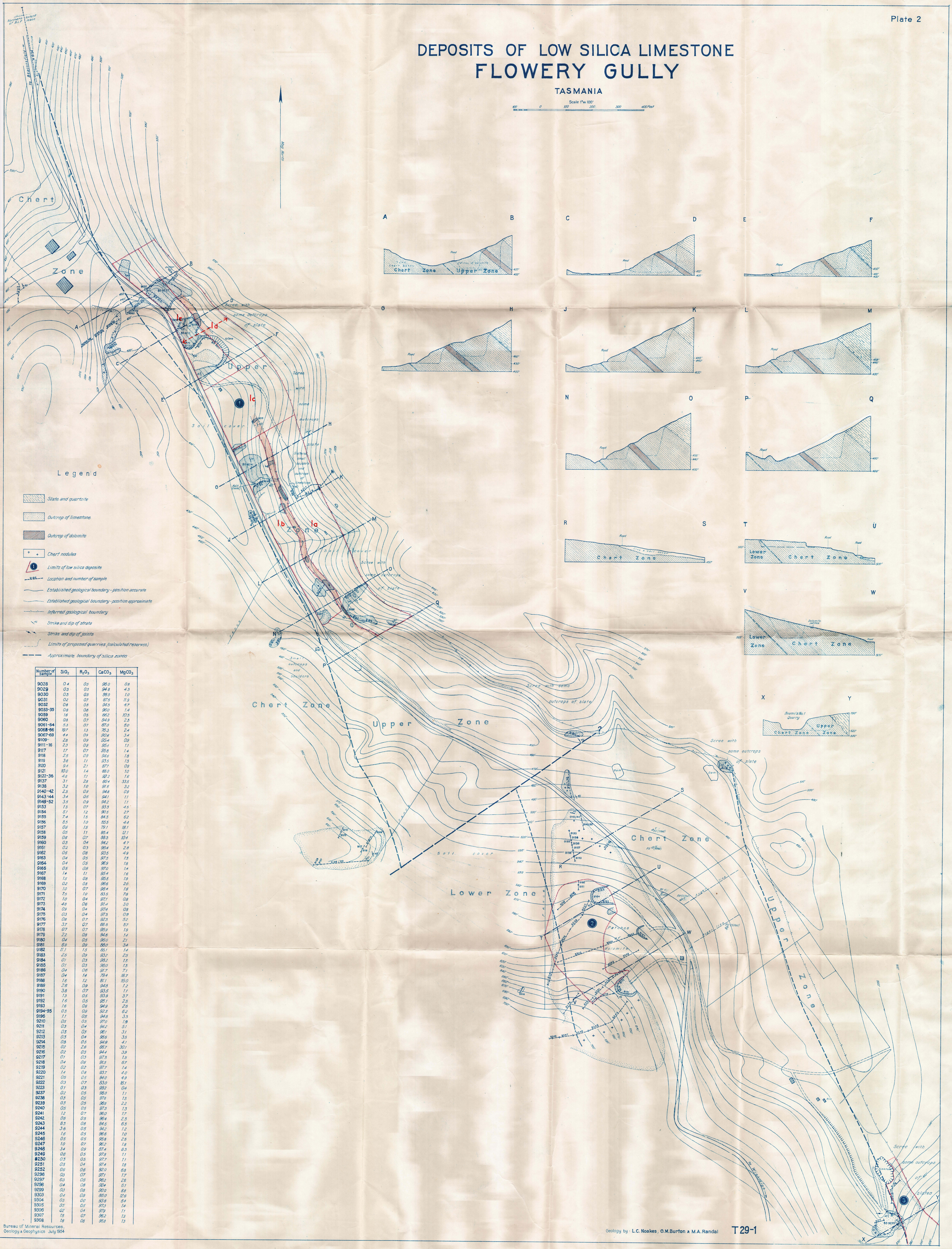


No.	SiO_2	R_2O_3	$CaCO_3$	$MgCO_3$	No.	SiO_2	R_2O_3	$CaCO_3$	$MgCO_3$
1	0.2	0.5	96.1	2.5	27	2.5	0.9	94.8	0.9
2	0.2	2.6	66.7	30.1	28	2.3	0.9	95.4	1.2
3	0.3	0.7	93.2	5.5	29	1.3	0.6	96.3	1.1
4	0.4	0.6	91.5	6.7	30	5.1	1.1	91.9	1.6
5	0.4	1.4	79.4	18.7	31	3.1	2.8	60.4	33.5
6	0.2	0.2	97.7	1.4	32	3.7	0.7	88.8	5.7
7	0.2	0.4	95.9	3.2	33	2.0	0.9	93.5	3.3
8	3.2	0.8	94.1	1.2	34	0.7	0.6	96.2	2.1
9	1.3	0.5	93.9	3.7	35	0.3	0.5	97.5	1.5
10	2.3	1.1	85.1	10.5	36	1.2	0.7	96.0	1.7
11	0.3	0.5	91.6	7.6	37	6.5	0.8	87.4	5.1
12	0.4	0.5	96.4	2.5	38	1.0	0.6	96.2	1.8
13	2.0	0.7	94.2	2.3	39	3.4	0.9	87.4	8.3
14	1.7	0.9	89.6	7.2	40	1.0	0.5	95.6	2.4
15	1.1	0.5	94.8	3.3	41	1.6	0.8	90.4	7.0
16	1.6	0.8	96.1	1.1	42	5.6	0.8	87.9	5.4
17	2.7	0.8	94.2	1.6	43	6.4	1.0	88.4	3.8
18	3.0	1.0	93.8	1.4	44	0.9	0.6	94.0	3.4
19	2.6	0.9	94.2	1.6	45	0.5	0.5	97.3	1.4
20	3.6	1.3	85.4	9.0	46	0.3	0.7	89.9	9.0
21	11.1	1.0	84.2	3.1	47	0.6	0.8	93.5	4.9
22	0.4	0.5	96.0	2.1	48	0.3	0.8	91.2	7.5
23	2.2	0.8	94.6	1.4	49	1.8	0.8	95.8	1.3
24	0.6	1.1	83.3	11.5	50	1.5	0.7	96.2	1.3
25	5.6	1.1	88.4	4.5	51	0.3	0.3	95.3	3.7
26	2.6	0.7	95.2	1.0	52	0.3	0.6	96.6	2.1
					53	0.2	0.4	97.9	1.1

Bureau of Mineral Resources
Geology & Geophysics, August 1954

T29-2
H.F.B.

DEPOSITS OF LOW SILICA LIMESTONE
FLOWERY GULLY
TASMANIA



Number of sample	SiO_2	R_2O_3	$CaCO_3$	$MgCO_3$
9028	0.4	0.5	98.0	0.8
9029	0.3	0.5	94.8	4.3
9030	0.3	0.5	98.0	1.0
9031	0.2	0.7	87.5	11.9
9032	0.6	0.5	94.3	4.7
9033-35	0.8	0.6	96.0	1.4
9059	1.6	0.5	86.2	10.3
9060	0.8	0.7	94.9	2.3
9061-64	5.3	0.7	87.0	6.0
9065-66	19.7	1.3	76.3	2.4
9067-69	4.4	0.9	90.6	3.4
9109	2.8	0.9	95.4	0.9
9111-16	2.3	0.9	95.4	1.1
9117	1.7	0.7	95.8	1.4
9118	2.5	0.9	94.6	1.8
9119	3.8	1.1	93.5	1.3
9120	9.4	2.1	87.7	0.9
9121	10.0	1.4	88.0	1.0
9122-36	4.8	1.1	92.2	1.6
9137	3.1	2.8	60.4	33.5
9138	3.2	1.0	91.6	3.2
9140-42	2.5	0.9	94.8	0.9
9143-44	3.4	0.6	94.1	1.1
9149-52	3.5	0.9	94.2	1.1
9153	1.3	0.7	93.3	4.5
9154	5.1	1.2	90.5	2.7
9155	7.4	1.5	84.3	6.2
9156	8.5	1.0	85.5	4.4
9157	0.6	1.5	79.1	18.1
9158	0.5	1.1	85.4	12.1
9159	0.6	0.7	88.3	10.4
9160	0.3	0.4	94.2	4.7
9161	0.2	0.3	96.4	2.8
9162	0.6	0.8	93.5	4.9
9163	0.4	0.5	97.5	1.3
9164	0.4	0.5	96.9	1.8
9165	0.5	0.6	97.0	1.4
9167	1.4	1.1	95.4	1.6
9168	1.5	0.8	95.5	1.9
9169	0.2	0.8	96.6	2.0
9170	1.0	0.7	96.4	1.6
9171	7.5	1.0	83.5	7.8
9172	1.0	0.4	97.1	0.8
9173	4.0	0.6	91.4	3.0
9174	0.9	0.4	97.4	0.8
9175	0.3	0.4	97.3	0.9
9176	0.8	0.7	92.3	5.2
9177	3.7	0.7	88.8	5.7
9178	0.7	0.7	95.9	1.9
9179	2.2	0.8	94.6	1.4
9180	0.4	0.5	96.0	2.1
9181	6.9	0.9	88.0	3.4
9182	11.1	1.5	85.1	1.4
9183	2.5	0.9	93.2	2.5
9184	0.1	0.3	98.2	1.3
9185	0.1	0.3	98.0	1.3
9186	0.4	0.6	91.7	7.1
9187	0.4	1.4	79.4	18.7
9188	1.6	1.2	81.1	16.0
9189	2.6	0.9	94.8	1.2
9190	3.8	0.7	93.5	1.1
9191	1.3	0.5	93.9	3.7
9192	1.6	0.5	95.1	2.3
9193	1.6	0.6	94.9	2.6
9194-95	0.3	0.9	92.3	6.2
9196	1.1	0.5	94.8	3.3
9210	0.5	0.5	97.0	1.9
9211	0.3	0.4	94.2	5.1
9212	0.3	0.3	96.1	3.1
9213	0.3	0.4	95.6	3.5
9214	0.3	0.5	94.9	4.1
9215	0.2	2.6	66.7	30.1
9216	0.2	0.3	94.4	3.9
9217	0.1	0.3	97.3	1.5
9218	0.4	0.6	91.5	6.7
9219	0.2	0.2	97.7	1.4
9220	1.4	0.8	93.7	4.0
9221	0.5	0.5	94.0	4.9
9222	0.3	0.7	83.0	16.1
9223	0.1	0.3	99.2	0.4
9237	0.2	0.5	98.0	1.1
9238	0.3	0.5	97.8	1.3
9239	0.3	0.5	96.9	2.2
9240	0.5	0.5	97.5	1.3
9241	1.2	0.7	96.0	1.7
9242	0.6	0.5	96.4	2.3
9243	8.3	0.8	84.5	6.3
9244	3.6	0.5	94.2	1.2
9245	1.6	0.5	96.6	1.0
9246	0.5	0.5	95.8	2.5
9247	1.0	0.7	96.2	1.8
9248	3.4	0.9	87.4	8.3
9249	0.6	0.5	97.8	1.1
9250	0.3	0.5	97.7	1.1
9251	0.3	0.4	97.4	1.8
9252	0.6	0.6	92.0	6.8
9296	0.3	0.7	97.1	1.7
9297	0.3	0.6	96.2	2.6
9298	0.4	0.8	92.4	6.1
9299	0.3	0.8	90.0	8.8
9303	0.4	0.9	86.0	12.6
9304	0.3	0.6	93.8	5.4
9305	0.5	0.5	97.3	1.4
9306	0.2	0.4	97.9	1.1
9307	1.5	0.7	96.2	1.3
9308	1.8	0.8	95.8	1.3

Bureau of Mineral Resources, Geology & Geophysics July 1954

Geology by : L.C. Noakes, G.M. Burton & M.A. Randal

T29-1