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THE LIMESTONE RESOURCES AND GENERAL GEOLOGY AND GEOMORPHOLOGY OF FLINDERS ISLAND

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The Limestone Resources and General Geology and Geomorphology of Flinders Island

INTRODUCTION

The purpose of the investigation was to make a geological survey of the limestone resources of Flinders Island, with particular attention to their economic possibilities, as part of a general description of the limestone resources of Tasmania.

To this end, the Island was adequately covered, and the principal limestone deposits delineated and contoured on a scale of four inches to the mile, with a fifty foot contour interval. The four inch maps (maps 3 - 7) show practically the whole of the western side of the Island, where the main workable deposits of limestone occur; but no attempt was made to contour those parts known to consist wholly of rocks other than limestone as this was beyond the scope of the investigation; nevertheless, those areas had also to be examined sufficiently to eliminate them as possible producers of limestone, because outcrops of that rock were possible in all parts of the Island wherever Kainozoic and Post Kainozoic Strata were to be found.

The base map was sheets 1, 2, 3, and 4 of the map of the Furneaux Group, on a scale of two inches to the mile, issued by the Surveyor General's office, Hobart, and showing the boundaries of the original purchases from the Crown, as well as some natural and other features. Chain, compass and clinometer traverses were run to established points, and traverses were checked by taking vertical and horizontal angles with director, at major stations.

Sixty-one samples of limestone were taken at various localities, wherever pits, quarries or natural outcrops made significant and representative sampling possible. These samples were analysed at the Departmental Laboratory, Launceston, and the results of analysis of the acid soluble part, expressed as parts per cent lime, magnesia, alumina, ferric oxide and phosphoric anhydride, are given in the table hereunder, together with parts per cent carbonate of lime, which is, in each case, calculated from percentage lime found by analysis.

General Information:

The Furneaux Group of Islands lies directly North of the north eastern extremity of Tasmania, from which it is separated by the fourteen mile wide channel of Banks Strait. Flinders, Cape Barren and Clarke Islands are the major members of the Group, which also includes a great number of lesser islands. Flinders Island is by far the largest member of the Furneaux Group, being approximately forty miles long by twenty miles wide and having an area of about eight hundred square miles.

The Furneaux Group was discovered in 1776, on Cook's second voyage, by one of his officers, Captain Furneaux who, however, thought it was part of a land connection between Tasmania and the mainland of Australia. Flinders visited the Islands twice in 1798 and demonstrated their insularity, referring to Flinders Island as "The Great Island of Furneaux" a name which it was to bear for some time. It remained uninhabited, except for occasional sealers, until about 1830 when it became the home of what then remained of the aboriginal Tasmanian tribes, and a settlement was formed at Emita, where the remains of it are still to be seen. The settlement was abandoned in 1846, and subsequently the Island was leased as a whole to various people. Tin was reported in 1871 by C. Gould, then Government Geologist, and in 1882 production began on Tanner's Bay Tinfield. The Island was thrown open for selection in 1888. In 1898 tin was produced on the Pat's River Tinfield. Small parcels of tin have been produced since, from time to time, but tin mining is not a major activity on Flinders

Island. The principal occupations are pastoral, and the grazing lands are particularly noted for their carrying capacity and the high quality of the stock they produce.

Communications are fairly good. A made road extends from Lady Barron on the south coast, via Whitemark and Emita to Palana in the North. From this main road several other roads and tracks branch off to more or less remote parts of the Island. Pat's River Aerodrome, North of Whitemark, receives two passenger and mail planes per week, and there is an air freighter service, as well as less frequent shipping services, both to Launceston and Hobart. By wireless telephone, the Flinders Island telephone system is connected with the telephone system of Tasmania.

<u>Previous Work</u>:

Strzelecki visited Flinders Island, and recognised that it consisted fundamentally of granitic rock. He mentions raised beaches on the south-west point of the Island. His "Physical Description of New South Wales and Van Diemen's Land" published in 1845, contains a map, based apparently on the chart by Stokes. Stokes' chart is still the basis of the Admiralty chart of the eastern part of Bass Strait.

In 1877 R.M. Johnston spent some time on Flinders Island. The Furneaux Group is mentioned in his "Geology of Tasmania", and at greater length, in a paper read before the Royal Society of Tasmania in 1878. He divides the Kainozoic and Post Kainozoic rocks as follows:

1. (A) Consolidated sandstone replete with shells of two or three small species of Helicidae and other land shells. Sometimes 60 and 70 feet thick.
2. (B) Elevated consolidated sea beaches and sandbanks, composed principally of the

shells of species not now existing. Average elevation 40 to 50 feet above present sea level.

3. Turritella limestone, composed of the more or less perfect remains of shells not now existing.

He also gives lists of fossils, and a geological section across the south end of Flinders Island.

In 1916 L.L. Waterhouse, then Government Geologist, made a geological reconnaissance of Flinders and Cape Barren Islands and furnished a brief report.

Subsequently several Departmental reports on Flinders Island were made, but they referred to small areas of the Island, or restricted aspects of its geology. Thus in 1931, P.B. Nye, then Government Geologist, reported on boring for water at "Wingaroo". Mr. Nye gives a bore log and list of fossils. In 1944 S. W. Carey, then Government Geologist, made an interim report on the possibility of petroleum on Flinders Island. Dr. Carey took samples of foraminiferal limestone at Palana, Emita, Whitemark, and Ranga, which were later determined by the Commonwealth Palaeontologist to be of Pliocene age, and suggests the possibility of older Kainozoric sediments below the limestone. In the same year, a confidential Divisional Report of the Division of Soils of the Council for Scientific and Industrial Research was made by C.G. Stephens and R.J. Wilson. The whole of Flinders Island was mapped according to soil type, and a comparison was made with the soils of King Island.

The only comprehensive geological description is the report entitled "The Furneaux Group of Islands", by F. Blake, 1947. Mr. Blake gives a full account of the Geology and Physiography of the Group, supplemented by a mile to the inch scale geological map on which essential topographical features are also shown. Map No. 2 of the present report, exclusive of sections, is based on Mr. Blake's map.

In the latter half of 1949 Mr. H.G.W. Keid, Chief Geologist of the Mines Department, made detailed reports on the mineral deposits and underground water supplies of Flinders and Cape Barren Islands.

Tectonic Relationships

A broad belt of rocks and islands stretches from Wilson's Promontory to the Furneaux Group. The width of the belt is given by the distance between Hogan and Curtis Groups. Along its eastern side the belt includes Seal Islands north east of Wilson's Promontory, Hogan Group, Kent Group and a number of smaller islands between Kent Group and Flinders Island. On Flinders Island itself, the continuation of this line runs from Blight Point to Mount Blyth, Mount Boyes, the hills in the Lughrata district, the Darling Range, the Dutchman and Vinegar Hill, extending through Vansittart Island to the mountains along the East coast of Cape Barren Island. From this line there are two offshoots, namely :- the first, eastward from the Darling Range to the Patriarchs and Babel Island, and the second from Mount Blyth through Quoin Hill and North Point, to the Sister Islands.

The western side of the belt runs from Great Glennie Island, through the Curtis Group, with a longish gap to Pyramid Rock, and thence to the western outliers of the Furneaux Group. Wilson's Promontory is in the middle of the belt at its northern extremity, and several rocks and small islands lie between it and Flinders Island, along the middle of the belt.

In contrast to Flinders Island, which has shallow water on its eastern, southern and western sides, the northern links of the island chain rise precipitously from water of an average depth of thirty fathoms. Strzelecki regarded the chain of islands as a series of peaks of portion of a southern branch of the Great Dividing Range, now covered by the sea and compares the islands rising from the Straits to peaks of the Andes seen above the clouds. The general aspect of these smaller islands is undoubtedly indicative of drowning, the time of which has been estimated as being within the last million years, the cause given as eustatic change of sea level (Carey, 1945). The flat plains of Flinders Island give it an appearance different to that of the smaller islands, but a rise from fifty to one hundred feet of the sea level would result in the complete disappearance of the plains beneath the waves, and the geological evidence from Flinders Island points unmistakeably to emergence after drowning.

The general direction of the island chain, and of the hills and mountains of Flinders and Cape Barren Islands, is north westerly, which is similar to that of the valleys of the Derwent, Tamar, South Esk and lower Gordon and of Macquarie Harbour and the Western Tiers, all of which vary between 300° and 325°. This common orientation has been cited by Dr. Carey as evidence of Miocene block faulting, suggesting that Flinders, Cape Barren and Clarke Islands are block faulted masses with the logical possibility that some of the mountain ranges, particularly on Flinders Island, are fault scarps or fault-line scarps. Positive evidence of faulting is lacking, but there are suggestive indications.

Extending from a point north of Whitemark in a south easterly direction to Ranga, and roughly parallel to, and between one and two miles from the coast, is a long straight escarpment marked by outcrops of granite and quartzite. This topographical feature seems to be a fault line scarp - an ancient fault first eroded then buried under limestone deposits, but now again revealed by removal of much of the limestone. It is also remarkable that the greatest depth in the waters of the eastern part of Bass Strait is between Flinders Island and West Sister Island, where three soundings of over seventy and one of over eighty fathoms have been recorded, depths unequalled until the extreme outer edge of the continental shelf is reached, 40 miles eastward. A deep trough fault, or graven, is indicated. Some years ago, an eatthquake was reported from Flinders Island, and this disturbance, from observations of witnesses, must, at Emita, have reached an intensity of V on the modified Mercalli scale of earthquake intensities. The rumble of the surface oscillations was heard approaching from the west, where renewed movement along an old fault is an obvious explanation of the earthquake.

Geomorphology:

Two strongly contrasted types of relief dominate the topography of Flinders Island, namely the flat plains, everywhere less than one hundred feet above sea level, and the mountains, ranging up to over two thousand five hundred feet above sea level. Country intermediate between mountain and plain types covers a smaller area, but is more important economically, because it contains much good pasture land, and tin bearing wash, and extensive areas of limestone. The limestone country, itself, has its own peculiar microtopography which will be described in the section dealing specifically with the limestones.

The granitic massif of the Strzelecki Peaks (2,550') and other mountains at the southern end of the Island is the most conspicuous feature. It is flanked by a very narrow coastal plain on the western side, and by a broad one, the Bootjack Flat, on the eastern side. Transition from one type of relief to the other is abrupt. About two miles of plateau country, with an average elevation of two hundred and fifty feet above sea level, extends on the northern side of the massif to the Darling Range. This plateau descends gradually to the broad eastern coastal plain; but the descent on the western side is sharp, and marked by outcrops of granite and quartzite. The western coastal plain broadens to a width of about a mile at Ranga, whence it extends to the north of Whitemark, bounded on its eastern side by the edge of the plateau, which merges with the coastal plain south of Pat's River. Towards the headwaters of Pat's River there is a continuation of the Darling Range to the North East, pointing to the granite hills of the Patriarchs and Babel Island; but a gap exists between the Darling Range and the hills clustered round the Sugarloaf. These last extend westward and cut the western coastal plain at Sawyer's Bay. The eastern coastal plain is a flat expanse, about six miles wide, extending from the Darling Range to the eastern coast, with only occasional low sand hills to break the monotony. North of the hills at Emita, which are continuous with the hills about the Sugarloaf, is a narrow coastal plain with coastal sand dunes, and also long sand dunes, aligned parallel with the prevailing winds, pointing inland from the coast. This plain is backed by a range of hills, about five hundred feet in height, consisting of a limestone with a core of granite. There is a fairly sharp slope, marked by much sand, on the eastern side, down to the wide eastern coastal plain. Just north of Emita, the divide between the eastern and western plains is very low, and this locality on the eastern side is known as Heathy Valley. At Tanner's Bay, the low sandy coastline is broken by granite hills and mountains, which extend westwards to Cape Frankland and northwards to Killiecrankie Bay. From Mount Killiecrankie on the north side of Killiecrankie Bay, a range of hills runs northwards to Bligh Point. The northern coastline is rugged with granite cliffs, except where Pratt's River enters the sea at Palana. Here the country is low lying, with sand dunes.

The mountains are residuals of erosion, their sharp outlines the result of insolation and frost action. The lower hills have more rounded outlines, with a covering of scrub and sparse timber. The coastal plains meet the higher country abruptly and may have a complex origin. The eastern plain is a foreland developed by progradation, and by the formation of offshore bars, enclosing lagoons which later became filled in. Long sand ridges, parallel with the present coast, are frequent and represent former coast lines. These processes are still continuing. But in some places, notably eastward from Heathy Valley, there are smooth level pavements of granite, the result, apparently, of marine erosion. Thus the coastal plain may have begun as a plan of marine erosion until the sea, due to a rising coastline, became too shallow for further effective wave action, and material from the sea bottom began to be cast up on the beach, or accumulate as off-shore bars. Sand dunes enclosing lagoons extend at intervals right along the western coast from Loccota to Parry's Bay, and again north of Emita along Marshall Bay. These phenomena are associated with a rising coastline, as is evidenced by raised beaches in the Lughrata district. These raised beaches are about one mile from the coastline at an elevation of fifty feet, or thereabouts, above sea level and contain beds with shells of species still living in the sea nearby. Many of the shells, especially those of the gastropods, still retain their original colouring. Off-shore islands are numerous and in places tombolos are developing, the most notable example being Babel Island, which is in the process of being tied to the main island at Sella Point, by the growth of a cuspate foreland. Parry's Bay, north of Pat's River, is a wide tidal flat undergoing marine erosion. In this area there are basalt flows interbedded with limestones and sand. Pebblesand boulders of basalt are used as tools by the incoming tides to grind away and underlying limestones, which, in some places, have been worn down to paper thinness, and in others have been worn away completely, exposing underlying beds of sand. Along the coastline as a whole, precipitous granite cliffs, descending abruptly into deep water, alternate with long sandy beaches and tidal flats, and all the evidence indicates partial emergence after drowning.

The drainage system varies with the topography. On the western side of the Island it is normal, except on limestone country. With a moderate rainfall and restricted catchment area, the streams are small, but liable to sudden flooding after heavy downpours. In their lower courses valleys are mature, with often considerable depth of alluvium, but streams tend to be incised on a broad flood plain, indicating recent uplift. In nearly all cases, streams have to cut their way through sand dunes to reach the sea, and where they have been unable to keep their mouths free of blown sand, lagoons have formed behind coastal sand dunes. Pat's River, north of Whitemark is the largest stream on the western side of the Island and has a well developed tributary system. On the eastern side, most streams have too inconsistent and inadequate a flow to cross the broad coastal plains, and end in lagoons and marshes, miles from the sea. Several large lagoons, such as Burnett and Logan Lagoons and Cameron Inlet, receive waters from the hills, and other lagoons, in wet weather, and preserve a precarious and intermittent connection with the sea. North of the Patriarch Hills, Arthur River, Foo Chow Creek and Patriarch Creek are permanent streams, but in this area the drainage is usally from South to North, parallel with the sand ridges, which are fossil dunes of former coastlines, until the stream is able to break through them to reach the sea.

GEOLOGY

In the geology of Flinders Island is the same marked contrast that appears in the topography. Palaeozoic igneous and metamorphic rocks lie in juxtaposition with Kainozoic and Post Kainozoic lavas and uncompacted sediments.

The oldest rocks on the Island are the closely folded Silurian slates and quartzites belonging to the Mathinna Series, a geosynclinal facies, the basement rocks of which are unknown. These outcrop mainly towards the centre of the Island. The Sugarloaf consists entirely of these beds, which extend eastwards, as the hills on the southern side of Heathy Valley, and westwards across Pat's River Aerodrome to Double Corner, where they outcrop on the beach. They also extend north westerly to Mt. Arthur, near Emita. Other outcrops are along the scarp stretching south eastward behind Whitemark, and on the south eastern side of the Strzelecki massif to Big Badger Corner on the Coast. They are also to be found at the turnoff to Nelson Lagoon and to the south east of Lady Barron.

The Silurian slates and quartzites have been intruded by granitic rocks. These granites are not homogeneous, and there appears to have been more than one period of intrusion. A very fine-grained granite forms the more prominent portion of the coastline at Leeka, Emita and Loccota. At Emita, this fine-grained granite, which weathers a pale brown colour with well-defined curved horizontal jointing, has a superficial resemblance to a sedimentary formation. It is intruded by tongues and dykes and larger masses of a coarser granite, which weathers a light gray. Some granite of the Strzelecki massif is exceedingly coarse in grain, and has felspar phenocrysts some inches in length. Basic dykes occur in the granitic rocks, and are possibly differentiates of the same magma.

The granites outcrop mainly along the western side of the Island, Vinegar Hill, the Patriarchs and a few isolated hills between the Five Mile Lagoon and North Point being the only prominent outcrops on the eastern side. The most spectacular outcrop is the small massif containing the Strzelecki Peaks. This is a solid block of granite over five miles square with an average elevation of one thousand feet or more. Further north the mass containing Mt. Counsel, Mt. Hauland, Pillingers Peak, the Darling Range and Mt Leventhorpe is almost as large. The more prominent and irregular parts of the coastline usually indicate the presence of granite.

Thus, Trousers Point is an outcrop of granite, and Settlement Point and the neighbourhood of Emita. A large area extends eastward from Cape Frankland, and includes North West Peak and Mt Tanner. This area is separated from another one about Mt. Boyes, by the stanniferous gravels of Tanner's Bay Tinfield. Mt Blyth is part of a small granite area separated from the granite mass of Mt. Killiecrankie by intervening areas of sand and limestone. From Mt Killiecrankie a continuous belt of granite extends along the coast to Bligh Point. Except for a sandy area at Palana, the northern coast is continuous granite to North Point, and the entrance to the estuary of the Arthur River.

Lying directly on top of the granites are the Kainozoic and/or Post Kainozoic sands, gravels and limestones. These rocks cover by far the greater area of the Island; all that area, in fact, which is not taken up by outcrops of granite or Silurian slates and quartzites. In the vicinity just north of Pat's River Aerodrome, limestone lies unconformably on the upturned edges of the quartzite beds. However, limestones are not the lowest beds of the later formations, as in the Five Mile Lagoon district they overly sands and gravels. Some limestones may have been contemporaneous with some sands and gravels, according as the conditions of deposition favoured clear, deep water accumulations in one place, and shallow sandy or gravelly accumulations in another place. Sands are commoner on the eastern side of the Island, whereas sands and limestones are about equally common on the western side. Tin bearing gravels are confined to areas fairly close to outcrops of granite, but barren gravels are sometimes to be found some few miles from granite outcrops. The thickness of the sandy beds may not be very great. A bore put down near Wingaroo homestead passed through eighty feet of sands and clays and one thin bed of limestone, without reaching bedrock. The limestones, with a few thin beds of sand, have a thickness of over two hundred feet in the Ranga district.

Interbedded with the sands and limestones, and near the base of the limestone, are flows of basaltic lavas. The larger areas of basalt are along the coast at Petrifaction Bay, west of Lady Barron, and on the plateau East of Whitemark. Smaller areas are on the coast at Parry's Bay, at the contact of granite and sedimentary deposits east of Mt Leventhorpe, at Tanner's Bay, and on the western side of the main road, about two miles south of Palana. At Parry's Bay, the basalt underlies limestone, because pieces of limestone can be found containing basalt pebbles.

Beds of shells exist in the Lughrata district about one mile inland from the coast at Marshall Bay. As these shells are of the same species as those now found on the beaches in that locality, and in many instances even retain their original colouring, the beds must be of very recent date. They are about two feet in thickness, overlain by sand and underlain by calcareous clay. In some areas the beds seem to have been eroded, with removal of finer material, leaving behind a deposit of loose shells and finely divided limonite.

The youngest accumulations on Flinders Island are the alluvium in the creek beds and the sand dunes fringing the coast. Even with the sand dunes, however, two generations are apparent. In the Lughrata district long sand dunes stretch inland from Marshall Bay, where the main road curves to avoid their digitations. These dunes are partly covered by scrub and small trees, but do not seem to be entirely stationary. Along the coastline, everywhere, except where solid rock is exposed, dunes have been banked up at right angles to the prevailing winds from the sea. Water seepage from the surface through the dunes tends to consolidate the lower layers by introducing calcium carbonate which acts as a cementing agent. Pseudo stalactites, formed around dead roots, are also common.

Geological History

The oldest known rocks on Flinders Island, the Silurian slates and quartzites, were originally geosynclinal deposits of fine sands and muds, accumulating in fairly deep water on a continental shelf. These beds, already considerably distorted by submarine slumping, were then elevated and further folded by orogeny, probably in Devonian times. At the same time they were injected, and re-injected with granitic magma and metallogenesis occurred.

Prolonged erosion followed elevation and granitic intrusion. There are no formations, and therefore there is no evidence of submergence, between the Lower Palaeozoic and Upper Kainozoic Eras. An enormous period of time would be required to accomplish the erosion that has taken place on Flinders Island. According to any theory of their origin, the granites must have been emplaced under considerable sedimentary cover and these superincumbent rocks have been, in the greater part of the area, entirely removed. This has a bearing on the possibility of major occurrences of ore minerals on the Island. Metallogenesis is usually more extensive in the veins, dykes and apophyses, stemming from the parent magma to penetrate the sedimentary cover of an igneous intrusion, than in the magmatic zone itself. Therefore the removal of the covering rocks of the intrusion may have resulted in the removal of the major part of any associated concentrations of economic minerals. Tin, a metal characteristic of deep zones of mineralization, except for a small lode on Babel Island, has been found only in the alluvial deposits. Consideration of these points will show that large deposits of ore minerals are improbable on Flinders Island.

Widespread epeirogenic earth movements in Miocene times evidently extended to the islands of Bass Strait, because, as mentioned previously the orientation of the major geographical and topographical features is closely parallel to that on the main Island of Tasmania. From this epeirogeny emerged the basic tectonic units of which the topography of Flinders Island, now modified by erosion, is the outward expression.

Submergence again occurred, at the earliest according to available evidence, in Upper Pliocene times; but the drowning was gradual and accompanied by several regressions. Thus the lower strata deposited during this period were beds of gravel and sand, indicating conditions of shallow water deposition; then follow beds of limestone laid down in deeper water less distributed by influx of sediment from the land surface; but some thin beds of sand are intercalated with the limestones and occasional thin impervious beds of clay and calcareous clay are to be found interbedded with sands below the limestones. The stratigraphical position of the impervious beds has a bearing on the possibility of petroleum occurring on Flinders Island. The only possibly source rocks would appear to be the limestones which are uppermost, having some thin discontinuous impervious strata below, but not above them. The sands, which would be very suitable as reservoir rocks are, for the greater part, separated from the source rocks by an impervious band wherever this exists; the limestones themselves are usually very prous and faulting in them has not been observed; so that altogether it is very doubtful if any oil traps could possibly exist.

The upper Pliocene period also saw the extrusion of basaltic lavas. These lava flows were not extensive, and the basalts occur interbedded with the lower strata of the limestones. Another peculiarity of their distribution is that they are to be found at no great distance from large and prominent outcrops of granite, and in fact may almost be said to fringe the granite masses. The inference is that they are fissure eruptions along faults bounding granite blocks.

The limestones and other strata laid down during the period of submergence were subsequently, and after some vicissitudes, perhaps, elevated and eroded to their present condition. Meanwhile the streams transported comminuted material from their headwaters to deposit it at their mouths, building up the alluvial plains which now constitute rich grazing country, and the winds and tides co-operated in the formation of coastal plains, by the construction of banks and dunes of sand.

THE LIMESTONES

Distribution:

Limestones occurring on the eastern plains of Flinders Island are lithologically distinct from those occurring on the western side, and outcrop differently. On the eastern plains, deposits have been exposed in the valleys of small streams, on the floors of lagoons and in drains, but actual outcrops of any extent are rare. The known deposits, except for those exposed on the floors of lagoons, are usually buried beneath a cover of sand or gravel, and have been revealed accidentally. To locate further similar deposits pitting or boring would be required.

At two places limestone has been quarried; at one for agricultural lime, and at the other for road material. The former is on the property of W.G. Holloway (original purchase 27/15), on the other side of Vinegar Hill from Lady Barron, with which it is connected by a bush track. The latter place is a cut in a bank above a small creek, where uncompacted calcareous material, underlying surface sand accumulations, has been exposed. It is highly probable that deposits similar to these two, exist beneath surface deposits in the southern portion of the eastern coastal plain.

In the Five Mile Lagoon area, soft earthy limestone is exposed in two pits, one to the east and another just south of Wingaroo homestead. This material would be very suitable for local use, but there seems to be no great quantity of it. Small outcrops occur, in various parts of the district, of a very compact tough limestone, disposed in a bed about eighteen inches thick, thinning out laterally into clayey bands with hard nodules. On some lagoons are to be found thin, tough discs of calcareous material, about two inches in diameter which seem to be formed by evaporation.

The limestone deposits on the western side of the Island are much more extensive than those on the eastern side. There is a small remnant of a deposit overlying sand, on a hill on the southern coast just west of the mouth of Big River. At Loccota just where the road from Big River turns off the granite to enter the long straight section, occur two small outliers of limestone; and at Trousers Point, a few hundred yards to the west, there are a few acres of limestone of varying thickness overlying granite which has been well smoothed by wave action prior to the deposition of the limestone.

The narrow coastal plain between Loccota and Ranga contains no limestone until a point about two miles south of the junction of the roads to Loccota and Lady Barron. At this point a narrow tongue of limestone crosses the road as a long, low ridge with steep sides, and continues in a south westerly direction for a few hundred yards. Further inland, limestones fringe the foothills of the Strzelecki massif and run up both sides of the valley between the massif and Reid's Peak. This valley becomes a small gorge towards its head with steep cliffs of limestone on the northern side and of granite on the southern, the limestone on the southern side cutting out about half way up the valley, where a tributary stream enters.

The lower slopes on the western and southern sides of Reid's Peak are limestone, and a low ridge of limestone crosses the Loccota road just south of its junction with the road to Lady Barron. Then alluvium intervenes, but further out towards the coast there is a large area of limestone level with the general surface of the plain, which is not many feet above high tide level. This limestone seems to be of no great thickness, and passes laterally into calcareous clays, and sands with calcareous nodules, in the same way as the limestone beds in the Five Mile Lagoon district.

Several small areas of limestone occur along the lower slopes of what may be a fault line scarp, running north-westerly from Ranga, and there are other small outcrops north of Pat's River, overlying sand or granite, while other small areas, sometimes directly on top of the quartzites, are to be found on the narrowing plains which end at Sawyer's Bay.

On the plateau between Reid's Peak and Pillinger's Peak, at an elevation of about three hundred feet above sea level, there is a fairly considerable area of limestone overlying sand. A smaller area at a lower elevation, further to the north east, underlies the sand; but this appears to be a much thinner deposit, and is not raised above the general level of the plateau.

At Sawyer's Bay, granite hills crowd in on the coastal plain, which is there reduced to a narrow strip of alluvium. But in the neighbourhood of Emita, limestone again occurs, and is found resting directly on top of granite. North of Emita is the largest area of limestone on Flinders Island. It forms a range of hills rising to about six hundred feet, two miles inland from the coast, and extending northwards to the Five Mile Lagoon road.

Two not very large areas of limestone, separated by the alluvium of a small floodplain of a creek, occur on the northern side of Tanner's Bay in the district known locally as the "West End". Similar deposits are to be seen at Boat Harbour, and there are outcrops of limestone about half a mile from the junction of the Boat Harbour and Killiecrankie roads at a fairly high elevation.

A large area of limestone exists on both sides of the main road to Palana opposite Mt.Blyth and here the limestone overlies thick beds of loose sand.

Pratt's River crosses a large limestone area which it has practically severed into two portions by corrading down to underlying sand and gravel. Limestone occurs on the hillslopes on either side at heights in excess of four hundred feet.

Some small scattered outcrops of limestone are to be found on the sandy slopes overlooking the Arthur River. These are small residuals of erosion, often only some scattered pieces of rock. Some outcrops, however, are still large enough to be undoubtedly "in situ", and directly overlie loose sand.

TOPOGRAPHY

The limestone areas of Flinders Island have a characteristic microtopography, which distinguishes them from other parts of the Island, and connects them with limestone areas elsewhere. The subject has an economic interest insofar as topography is conductive or otherwise to easy quarrying conditions.

Theoretically, the important consideration is that limestone is much more liable to attack by solution than any other common rock, because the insoluble carbonate of lime of which it consists can be converted to the soluble bicarbonate by the action of water charged with carbonic acid. Usually, rain water which has absorbed carbonic acid gas from the atmosphere, does not confine its solvent action to the surface, but penetrates underground by pores and joints, to carve out caverns and tunnels in the rock. Eventually the caverns and tunnels collapse, and the debris, is then dissolved and swept away leaving behind residual areas demarcated by cliffs and sharp slopes, which are in turn attacked.

On Flinders Island the limestones, because of their extremely porous nature, have been perculiarly susceptible to erosion by solution, and the above processes have proceeded to an advanced stage. Except where protected by granite, the limestones have in most areas been almost completely removed, and erosion has bitten into the underlying beds. However, in the Ranga district erosion has proceeded only as far as the base of the thick limestone beds and the topography consists of low hills and ridges of limestone, with sharp slopes down to intervening areas of sand and alluvium. Limestones fringe the base of the mountainous granite areas with similar slopes and cliffs to alluvial flats.

Further northwards in the vicinity of the Pat's River aerodrome, limestone forms a capping to sandy hills, as here erosion has gone much deeper.

The flat plain of limestone in the Ranga district, extending to the coastal sand dunes and probably continuing underneath them to the coast, demands a special explanation. This limestone seems to be part of an extensive, but relatively thin bed. It is exposed on a low lying plain, only slightly above the water table, and therefore the water becomes saturated with lime, and tends to lie stagnant instead of flowing away. The drains now cut on the plain will facilitate removal of the limestone, although this is an enormously lengthy process, of course, on any human time-scale.

At Emita, the limestones rest directly on the granite which controls the topography. Small swallow holes, however, are numerous. Rain water proceeds underground by these holes, which are constantly being enlarged, until it reaches the granite, over which it flows to reappear as springs.

The limestone hills north of Emita do not show any topographical peculiarities. The relatively normal contours probably reflect the controlling influence of the underlying granite. Dry valleys and occasional small basin shaped depressions show the prevalence of underground drainage.

The limestone in the valley of Pratt's River has perhaps suffered slightly less erosion than that elsewhere on the Island. Only very fine contouring could indicate the very irregular surface here. Small domes and depressions are innumerable, as a result of solution and underground drainage.

On the western side of the Island there are no beds of limestone covering a sufficient area, or thick enough to exert any special influence on the topography.

Stratigraphy:

The foraminiferal limestones, the distribution of which has been described, are the uppermost sedimentary strata on Flinders Island, if local accumulations of dune sand be excepted. There are also alluvial beds, constituting the flood plains of creeks and rivers, which are still in the process of deposition, and therefore must be subsequent to the limestones; but these occupy an even more insignificant part of the total area of the Island than the dune sands.

In the Ranga district, limestone extends from within fifty feet of mean sea level to three hundred and forty feet above it; north of Emita, in the Lughrata district, it reaches from within fifty feet to four hundred and fifty feet above sea level; and from Pratt's River to the Quoin in the Extreme north of the Island, the limestone has a vertical range of five hundred feet.

Interbedded with this limestone are some very much thinner beds of sand, and occasionally the limestone itself is somewhat siliceous; but generally it exhibits a remarkable uniformity, both laterally and vertically. On the evidence of the foraminiferal remains it contains, the age of the limestone has been estimated by Miss Irene Crespin, Commonwealth Palaeontologist, to be between Upper Pliocene and Pleistocene, and deposition is said to have taken place in water less than fifty fathoms deep, and under temperate climatic conditions, similar to those now prevailing on the south eastern portion of the Australian continental shelf. The porosity and lack of compaction of the more massive portions of the formation suggests somewhat rapid deposition due to correspondingly rapid submergence.

Below the thick limestone beds, are beds of sand gravel and clay, with one or more beds of dense, tough limestone about eighteen inches in thickness and tending to thin out laterally and be replaced by clays containing calcareous nodules. Bores put down at "Wingaroo" in the Five Mile Lagoon district have penetrated as far as eighty feet into the sandy beds without reaching granite. The succession of limestone to sand and gravel indicates rapid submergence.

The limestones were best developed on the western side of the Island, where they must have been at least five hundred feet thick. Before erosion it is probable that limestone covered all the low lying country between the outcrops of granite and Silurian slates and quartzites on the western side of the Island, in contrast to the eastern side where, as only very small residuals are now to be seen, limestones must have been of no very great thickness, and were perhaps not represented at all in places.

On the western side, however, the sandy strata, which are seen to underlie the limestones in those localities where both formations are present, are often missing altogether and the limestone rests directly on the granites, slates or quartzites. The explanation would appear to be that the ancient rocks, where they directly underlie the limestone, were formerly small rocky islands, similar to those still fairly common in the surrounding waters at the present day, with precipitous slopes into deep water. This environment while conductive to the formation of limestone beds, which require clear deep water, would not result in the formation of any depth of sand.

Palaeontology:

The following lists of fossils have been taken from reports and publications by Johnston, Nye, Chapman, Singleton and Woods, and Crespin, listed in the bibliography hereunder.

A. Upper limestone formation on Western side of Flinders Island.

Foraminifera:-

Globigerina bulloides
Streblus sp.
Discorbis dimidiata
Rectobolivina
Anomalina sp.
Streblus beccarii
Textularia

Quingueloculina

Elphidium crispum

Gasteropoda:-

Helix stanleyensis

" pictilis

" wellingtonensis

A. Sands and limestone formation on Eastern side of Flinders Island.

No. 1 Bore, "Wingaroo", Flinders Island.

0 - 10'

Polyzoa :-

Cellepora

Pelecypoda :-

Marcia

Gasteropoda : -

Nassarius

Pyrazus

Amphipeplea

Ameria

10 - 55'

Pelecypoda :-

Cuspidaria exagara

Marcia corrugata

Ostrea

Chlamys asperrimus

Glycimeris

Pectunculus

Nuculana crassa

Codakia sp.

Katelysia peronii

Antigona gallinula

Gasteropoda: -

Sigapatella calyptraeformis

55 - 80'

Pelecypoda: -

Dosinia

Divaricella cumingi

Nuculana crassa

Clausinella placida

Marcia

Miltha grandis

Glycimeris radians

Cardium

Ostrea

Glycimeris convexa

Katelysia stregosa

Amphidesma crycinaea

Scaphopoda :-

Dentalium

Gasteropoda :-

Fusinus novae hollandae

Cancellaria

Conus anemone

Cantharidus fasciatus

Sigapatella calyptraeformis

Polynices conicus

Turritella Gunnii

" Australis

" Hookeri

Tylospira coronata

Zemira sp.

Eugyrina

Bankivia fasciata

Bittium diemenensis

Petrology :

The Flinders Island limestones are all of the non-recrystallised fragmental types. They vary greatly in their relative degrees of consolidation, some limestones on the eastern coastal plain, e.g. those at "Wingaroo" and Lady Barron, have hardly any degree of consolidation at all when fresh, although specimens exposed to the atmosphere invariably harden. The limestone of the Dutchman deposit is perhaps the loosest and least consolidated of them all, and could be shovelled up without difficulty. On the other hand, thinly bedded limestones exposed in the Five Mile Lagoon district, at Ranga, and at the foot of the eastern slopes of the low hills in the Lughrata district are extremely dense and tough. Although all intermediate stages of consolidation can be found, it is convenient, for practical purposes, to divide the Flinders Island limestones into three classes according to their degree of consolidation :-

(1) Unconsolidated types found usually as isolated deposits, often buried under sand, on the eastern plains.

(2) Lightly consolidated porous types, constituting the bulk of the limestone found on the western side of the Island. Surface capping and contained lenses of tough fine grained material are common.

(3) Well consolidated limestone disposed in rather thin beds, in the sands, etc. underlying the main deposits of porous limestone or outcropping on the eastern plains.

There is no correlation between the relative physical properties of these rocks and their lime content, but the physical properties determine, of course, the ease with which the rock may be processed, and also the purposes for which it is ultimately suitable.

(1) Seen under the microscope, the unconsolidated material is a mass of grains which are aggregates of very finely crystalline calcite. The grains are of various sizes down to very finely divided material. There are also single crystals of calcite in size of the order of .02 m.m., and rarer single crystals of quartz and falspar of about the same order of size. The material also contains organic matter in the form of root hairs, but organic remains belonging to the animal kingdom seem all to be of microscopic dimensions. It is apparently a deposit formed

in shallow disturbed water, poorly supplied with sediments from the land. Many of the calcite granules are heavily stained with iron. This description applies equally to samples from the deposits at Lady Barron and the Dutchman, the former being coarser in grain and poorer in lime.

Limestones of types 2 and 3 were examined in thin section :-

(2) Lightly consolidated porous type.

This rock consists essentially of organic remains including foraminiferal -------------tests, echinoid spines, holothurian remains and fragments of brzozoa and mollusca, all cemented together by very fine grained colourless, crystalline calcite. The shelly fragments are in size of the order of .02 m.m., except for accasional larger molluscan remains which are, however, rather rare and tend to occur in small pockets. Otherwise the grain size is remarkably uniform, and the calcite which cements the fragments together appears as a thin crystalline growth on the surface of the grains, and has the appearance of having flowed over them, leaving interstices which account for the high porosity of the rock.

The chief impurities are rather uncommon crystals of quartz and felspar, both rounded and angular, and much rarer crystals of topaz and garnet. The organic remains are faintly stained with iron and there are a few opaque grains of limonite. The quartz and felspar show little signs of alteration, although some of the felspar crystals are corroded.

It may be noted here that this rock would be easily broken down, by fracturing the thin cementing calcite, into the original fragments, and would then be a very suitable fineness for agricultural lime.

The loose and porous nature of the deposit suggests fairly rapid deposition, and its freedom from muddy sediment indicates very clear water receiving little detrital matter from any neighbouring land surface, while the organic remains show that general conditions must have been very similar to those now appertaining.

This type of limestone has given rise to a secondary variation. It often has a surface capping or contains lenses of a hard, tough rock, dense and without many pore spaces. The organic remains have been almost completely replaced by calcite, and concretionary laminae are frequent. This variety has arisen by the solution and redeposition of calcite in the rock.

At Emita, between the road to Emita Jetty and that up to the old wireless station, there is a loose and friable deposit of fine high grade material. In thin section it is a structureless aggregate of very fine grained semi-opaque material, although there are curved bands that may be depositional laminae. It seems to be a secondary deposit derived from a high grade porous limestone placed at a higher elevation.

(Samples F.I. 31, F.I. 21)

(3) Dense well consolidated type.

These limestones have a semi-opaque groundmass, enclosing organic remains, including foraminifera and broken fragments of Molluscs. In it are embedded angular, sub-angular and rounded grains of quartz and rarer felspar. With a high power objective, the groundmass may be resolved into a fine mosaic of calcite, and possibly some clay mineral which, however, is too fine-grained to be identified. There are also small rounded masses, and the infillings of shells and tests, consisting of coarser grained colourless calcite. The carbonate of lime content varies considerably from sample to sample, and the rock was originally a calcareous mud.

A variant of this type exists at "Wingaroo", in a pit just south of the homestead. It is less compacted and contains numerous pore spaces, and is soft and friable; but has a similar appearance under the microscope (Sample F.I. 56).

ANALYSES OF LIMESTONES FROM FLINDERS ISLAND

Reg. No.	Field No.	Map No.	Locality	acid insol.	Al_2O_3	Fe_2O_3	P_2O_5	MgO	CaO	$CaCO_3$ (calc)
577/49	1	8	W. Holloway's Quarry, Lady Barron floor - 9"	2.9	0.2	0.5	.01	1.8	51.2	91. 4
578/49	2	"	do 9" - 1'3"	9.7	0.6	0.7	0.02	1.7	47.3	84. 5
579/49	3	"	do 1'3" -3'11"	38.2	0.5	1.8	0.01	1.2	30.7	54. 8
580/49	4	"	do 3'11" -7'1"	24.7	0.2	0.9	0.02	1.6	38.8	69. 2
581/49	5	"	4 chains N.E. OF Holloway's Quarry	28.0	0.6	0.9	0.01	1.4	36.8	65. 7
582/49	6	"	10 chains N.E. of Holloway's Quarry	3.2	0.2	0.6	0.02	1.6	50.6	90.4
193/50	F.I.55	"	E. of Dutchman Hill	14.8	0.7	0.8	0.12	0.6	45.3	80.9
192/50	F.I.54	"	Pit, N.E. of Homestead "Wingaroo"	21.5	0.8	0.9	0.03	1.2	39.1	69.8
195/50	F.I.57	"	" " " " "	30.5	0.4	0.8	0.02	0.9	36.1	64.4
194/50	F.I.56	"	Pit, near Homestead, "Wingaroo"	22.1	1.6	1.0	0.04	1.1	38.8	69.3
816/49	F.I.53	3	Drain, S. of Ferguson's Jetty	36.8	0.2	0.3	0.03	1.1	33.0	58.9
815/49	F.I.52	"	" " " " "	33.6	0.2	0.4	0.04	1.1	34.8	62.2
727/49	F.I.38	"	Old stream bank, Ranga	24.4	0.3	0.6	0.11	0.7	40.3	72.0
726/49	F.I.37	"	J.A. Ferguson's property,Ranga	19.3	0.4	0.6	0.08	0.6	43.3	77.3
725/49	F.I.36	"	Cliff on P.Dart's property,Ranga	18.8	0.3	0.9	0.15	0.7	43.5	77.7
814/49	F.I.51	"	J.A. Ferguson's property,Ranga	3.0	0.1	0.2	0.2	0.6	52.1	93.0
812/49	F.I.49	"	S.G. Moyles purchase, Ranga	7.6	0.3	0.7	0.02	0.4	49.9	89.1
621/49	F.I.13	"	Sinkhole on J. Blunstone's,Whitemark	12.6	1.0	0.4	0.06	0.7	47.0	83.9

Reg. No.	Field No.	Map No.	Locality	acid insol.	Al_2O_3	Fe_2O_3	P_2O_5	MgO	CaO	$CaCO_3$ (calc).
548/49	F.I.1	3	Near School, Whitemark	4.5	0.4	0.4	0.02	0.5	51.6	92.2
549/49	F.I.2	"	" " "	12.6	1.0	0.4	0.06	0.7	47.0	83.9
639/49	F.I.19	4	Coast Parry's Bay	87.1	5.1	2.0	nil	0.4	0.7	1.2
636/49	F.I.16	"	" " "	38.0	2.5	1.3	0.01	0.6	29.1	62.0
637/49	F.I.17	"	" " "	26.9	2.2	1.4	0.01	0.5	36.8	65.7
638/49	F.I.18	"	" " "	19.0	1.0	1.3	0.02	0.6	41.4	74.0
619/49	F.I.11	"	Quarry on aerodrome reserve	10.3	0.6	0.6	0.01	0.7	47.4	84.8
620/49	F.I.12	"	" " " "	36.8	0.7	0.9	0.02	0.7	32.9	58.8
642/49	F.I.22	"	" " " "	34.7	0.4	1.3	0.03	0.7	32.6	58.2
634/49	F.I.14	"	Side of main road N. of aerodrome.	31.9	3.3	1.4	0.01	0.6	32.8	58.6
635/49	F.I.15	"	Quarry McKenzie's purchase 12/14	3.2	0.3	0.2	0.01	0.7	51.7	92.3
640/49	F.I.20	"	" " "	4.7	0.5	0.7	0.01	0.9	48.5	86.6
788/49	F.I.39	"	McKenzie's purchase N. of aerodrome.	23.6	1.2	0.8	0.03	0.6	39.1	69.8
724/49	F.I.35	"	Quarry W. side road, Blue Rocks.	26.0	1.8	1.3	0.02	0.8	37.0	66.1
723/49	F.I.34	"	Quarry E. side road, Blue Rocks.	20.1	0.9	0.7	0.01	0.8	39.5	70.5
797/49	F.I.40	5	Near R.Morton's homestead, Emita.	32.6	0.4	0.4	0.04	1.1	34.4	61.4

Reg. No.	Field No.	Map No.	Locality	Acid Insol.	Al_2O_3	Fe_2O_3	P_2O_5	MgO	CaO	$CaCO_3$ (calc.)
789/49	F.I.41	5	Coast S. of Jetty, Emita	3.7	0.5	0.4	0.05	2.5	48.7	87.0
643/49	F.I.23	"	" " " " "	5.9	0.3	0.7	0.06	1.5	48.6	86.8
675/49	F.I.33	"	Road to J.Woods house,Emita	14.5	1.3	0.9	0.04	0.6	45.8	81.8
672/49	F.I.30	"	J.Woods property, Emita	4.0	0.6	0.6	0.06	0.7	52.7	94.1
673/49	F.I.31	"	E. side road to Emita Jetty	0.2	0.1	0.1	0.01	0.7	53.3	95.2
641/49	F.I.21	"	Quarry on road to Wireless Stn. Emita.	0.2	0.3	0.1	0.03	0.8	52.0	92.7
674/49	F.I.32	"	Road to old Jetty, Emita	16.0	1.2	0.9	0.05	1.9	43.4	77.5
670/49	F.I.28	"	Near old Jetty, Emita	0.4	0.1	0.1	0.02	0.8	50.3	82.8
671/49	F.I.29	"	Road W. of Emita P.O.	14.7	0.2	0.4	0.02	1.3	44.4	79.3
617/49	F.I. 9	"	E.M. Cooper's purchase N.of Emita	19.2	0.5	0.4	0.03	1.2	42.1	75.2
618/49	F.I.10	"	E.side of main road, N.of Emita	21.1	0.3	0.5	0.05	0.7	42.4	75.7
666/49	F.I.24	"	A.R. Cooper's purchase,Lughrata	24.4	1.1	1.2	0.04	0.8	39.5	70.5
667/49	F.I.25	"	" " " "	13.5	0.7	0.7	0.02	0.5	46.4	82.9
615/49	F.I. 8	"		7.9	0.6	0.4	0.05	0.8	49.5	88.4
791/49	F.I.43	"	Pit,W.side of road Lughrata	27.5	1.2	0.8	0.05	0.5	37.6	67.2
792/49	F.I.44	"	" " " " "	12.3	2.2	0.2	0.04	0.9	43.9	78.4
668/49	F.I.26	"	A.T. Trueman's purchase Z 31,Lughrata	13.2	1.0	0.2	0.02	0.8	47.0	83.9
669/49	F.I.27	"	" " " "	5.9	0.6	0.6	0.01	0.6	51.7	92.3
614/49	F.I.6	"	Lughrata	7.9	0.6	0.6	0.05	1.3	48.9	87.3

Reg. No.	Field No.	Map No.	Locality	Acid Insol.	Al_2O_3	Fe_2O_3	P_2O_5	MgO	CaO	$CaCO_3$ (calc.)
615/49	F.I.7	5	Lughrata	0.5	0.4	0.1	0.01	0.8	48.9	94.8
550/49	F.I.3	"	A.Stackhouse's purchase, Lughrata.	26.4	1.5	1.5	0.06	0.7	37.5	70.0
551/49	F.I.4	"	A.Stackhouse's purchase, Lughrata.	19.7	0.5	0.6	0.01	0.7	42.4	75.7
552/49	F.I.5	"	" " "	9.4	0.3	0.2	tr.	0.7	48.0	85.7
793/49	F.I.45	"	Quarry E. side main road "	13.3	2.1	1.2	0.05	1.0	43.3	77.3
794/49	F.I.46	"	" " " " " Lughrata.	11.4	2.6	0.9	0.03	0.8	44.8	80
790/49	F.I.42	"	Lughrata W.of main road.	19.0	1.4	0.5	0.06	0.4	41.9	74.8
795/49	F.I.47	4	W.side of main road, Lughrata.	5.9	1.0	0.6	0.05	1.2	48.6	86.8
238/50	F.I.58	"	South of road to Wingaroo	15.6	1.2	0.9	0.02	0.6	43.1	77.0
241/50	F.I.61	"	N.side of road to Wingaroo.	4.4	0.4	0.5	0.06	0.6	53.2	93.2
240/50	F.I.60	6	Pit W. of main road near Killiecrankie	15.8	0.3	0.7	0.04	0.6	42.7	76.4
239/50	F.I.59	7	Palana.	10.2	0.3	0.7	0.08	0.9	47.9	85.5

Note on the Analyses

The principal impurities of the Flinders Island limestones are sand and clay, both insoluble in acid. There is also, on the average about one percent each of magnesia and alumina and a minute proportion of phosphorus anhydride in combination. Oxides of iron are present to the average amount of one per cent, as the mineral limonite, which is the colouring material in the rock.

The extreme variation in calculated carbonate of lime content is from 52% in a somewhat clayey rock from Parry's Bay, to 95.2% in a white powdery reprecipitated limestone from Emita, in which the chief impurity is probably also clay. Between these extremes there is a wide scatter, but the limestones in any one deposit are of fairly even quality, and a reasonable estimate of the grade of limestone from that deposit may be made. The samples are, however, of differing orders of importance, because, whereas some samples represent a normal type which is present in quantity, others are of peculiar types having a more limited distribution. This aspect of the analyses will be discussed later when particular deposits are mentioned.

The rocks are "straight" limestones with the impurities introduced during deposition by normal physical conditions in fairly shallow water. The term "calcareous sandstone" used by Johnston has not been found applicable to any of the rocks examined.

Utilization:

Before recommendations concerning the working of the Flinders Island limestones can be made, consideration is necessary of the possible uses to which they could be put.

These limestones have been used to a small extent in the past, although their present use is practically nil.

They were used as building stone in the early days at the Settlement and stone foundations are still standing there. Limestone was quarried and crushed in a small way on W.J. Martin's original purchase ($\frac{8}{5}$) at Ranga. Unconsolidated calcareous material has been quarried on W. Holloway's original purchase ($\frac{27}{15}$), north of Lady Barron, and exported for use as a filler with fertilizer.

Three uses suggest themselves immediately:-

1. Crushed limestone for agricultural lime.
2. Broken stone for road material.
3. Trimmed stone for building.

For agricultural lime the stone would need to be fairly finely ground. Particles larger than 10 mesh acquire reaction shells which prevent further solution; but particles as fine as 60 mesh are reputed to be as efficient as burnt lime. As previously noted, the porous foraminiferal limestones of Flinders Island would naturally break up to give particles of approximately this fineness, or finer. The lime content of the material crushed is a factor to be considered here, in relation to ease of crushing, cost of transport, and other factors. It may be more economical to crush a lower grade but more friable stone, offsetting ease of crushing against the cost of transport of the slightly higher quantity of material required. It is important to select a site and employ methods that will allow as much as possible of the material directly available to be used and obviate the hazards and expense of selective quarrying; the finding of uses for all the types of material available is, of course, another method of overcoming this difficulty. Due consideration has not been given, it appears, in the past to these various aspects of the problem, and grade of material, solely for use as agricultural lime, has been pursued to the neglect of all other factors.

Alternatively to crushing, limestone may be burnt to give the oxide, which may be used directly or hydrolysed to give slaked lime, the hydrolysis converting the lumps of burnt lime to a very finely divided powder. In this process the purity and physical properties of the stone are important considerations, a purer, denser stone being better than an impure, porous and friable one. The stone described under "type 3", would be the most suitable one for the purpose. Burnt lime is necessary for mortar.

It would appear to be well established that application of lime would be of benefit to most of the soils on Flinders Island, especially virgin soils in areas to be freshly opened up for grazing and agricultural purposes. As well as supplying nutrient calcium, and improving the physical conditions by helping to granulate dense soil, lime is of importance to correct acidity. Normal plant life does best in slightly acid soil, but in soils so acid as to have a pH less than 5, iron and aluminium may be present in solution in such quantity as to be toxic. Lime is very important in the growth of leguminous plants and through them in the fixation of atmospheric nitrogen. However, where there are soil deficiencies, more than simple treatment with lime is needed.

Limestone would be a very suitable material for the foundation of the light roads on Flinders Island. It has sufficient strength for such roads and is much more readily handled than the stronger, but more intractable, igneous and metamorphic rocks, used for heavy traffic roads. As a road material, the tougher and denser kinds of limestone are the more suitable, and "type 3" limestone would be very useful. Over a foundation of hard limestone, the less consolidated limestone or weathered granite debris could be spread to give a binding surface.

Porous non-crystalline limestones make excellent building material because of their low density and ease of working. A useful peculiarity is that while soft and easily quarried and worked, they acquire an indurated surface on exposure. By capillarity, carbonate of lime is brought to the surface and deposited as a fine grained film which fills the pores and interstices to give a tough and durable outer covering to the stone. The limestone described under "type 2", with little quartz and few fossil remains, would, in all probability, be readily cut with a steel saw.

Recommendations:

Sufficient information has been presented in the foregoing pages to warrant specific recommendations for the utilization of the Flinders Island limestones.

While the principal use of the limestones would inevitably be as crushed limestone for agricultural purposes, the auxiliary uses for which they are very suitable should not be neglected. But whatever the use to which the stone is put, it is of primary importance that working faces be as close as possible to a suitable road, for ease of transport. The grade of limestone is of course, also a principal factor, together with the facility with which it may be worked.

At this stage many alternative sites for the production of limestone suggest themselves, together with the question of whether there should be only one site or more than one. If a crushing plant and a saw were to be installed it would not be economical to duplicate them on Flinders Island, merely to serve local needs, but deposits of unconsolidated limestone, as at Lady Barron and Dutchman Hill, could be worked without raising this objection. Conversely, the fact that there is no consolidated limestone at either of these localities precludes either of them from being the sole source of limestone if the solid stone is to be quarried. Another objection to either locality being selected in exclusion to all others, is that neither of them is centrally placed with regard to the island as a whole. Regarding the grade of limestone available, neither are high grade deposits. From the Lady Barron quarry, limestone averaging 65% carbonate of lime might be expected, although thin bands of much higher grade materials are present. From the Dutchman Hill deposit, the only sample taken gave 80% carbonate of lime, although it is doubtful if that grade could be maintained. The great advantage of those two deposits is, of course, that no crushing is required, although the Lady Barron material would have to be freed from hard nodules, and that from Dutchman Hill from the very large lamellibranch shells it contains. Moreover, these two deposits are the nearest to two areas where lime would be very effective, namely the Lady Barron quarry to the Bootjack Flat, and the Dutchman deposit to the Nelson Lagoon area. Both these deposits could be usefully worked as auxiliary sources of agricultural lime.

In the same way the slightly consolidated deposits at Wingaroo could be worked for local use, small quantities being easily crushed without special mechanical aid; but the deposits seem to be quite small. The tough, consolidated limestones in the Five Mile Lagoon district could find only a limited local use as road metal, as they occur in rather thin beds and would have to be spalled on the spot.

A deposit of high grade limestone, which could be fairly easily worked and would require little crushing, exists at Emita. This deposit is apparently of lime that has been dissolved and reprecipitated in a powdery form.

It is the highest grade limestone of which samples were collected, one sample giving 95.2% carbonate of lime and the other 92.7%. The site of this deposit is on both sides of the road to the old wireless station and quite a fair amount of material would appear to be available.

The remaining areas to be considered are all outcrops of the lightly consolidated foraminiferal limestones which occupy large areas of the western coastal districts of Flinders Island; and it is here that the opening of a quarry to produce crushed, dressed and coarsely broken stone is recommended. The quarry would need to be as close as possible to a satisfactory road, and to be placed on a suitable slope to obtain a good working face at an early stage, a well drained floor, and gravity feed to crusher, and gravity loading of the crushed material.

In regard to quantity, quality and type of material available at the various localities, reference to the table of analyses shows that each of eleven samples contained more than ninety per cent carbonate of lime. Of these, two (1,6) from W. Holloway's property north of Lady Barron are from thin beds of limestone and do not give a true idea of the grade of the bulk of the material. Sample F.I. 51 from J. Ferguson's property, Ranga, and samples F.I.27, F.I. 7, Lughrata were taken for special purposes and may be neglected for similar reasons. Sample F.I. 15, near Pat's River, is from quite a small deposit and samples F.I. 21, F.I. 32, Emita,are of a peculiar deposit, which has already been described. Sample F.I. 30 from J. Wood's property, Emita, is from a locality unsuitably placed for quarrying. The sample taken in the vicinity of Whitemark Area School(F.I. 1) gave a higher percentage of lime than two others (F.I.2,

F. I. 13) taken nearby, but an average grade of more than eighty per cent carbonate of lime would probably be obtained. However, the locality is not particularly suited to quarrying, and there is some doubt about the thickness of the limestones here. Although centrally placed, the pasture lands about Whitemark, itself, have no special need of lime. Other samples giving favourable analytical results, F.I. 49 on S.G.Moyle's property and F.I. 28 near the old jetty at Emita, are not from localities suitably placed for quarrying, nor where a large quantity of stone could be expected. Sample F.I. 59 from Palana indicates a good grade stone, and there is much good material suitably placed for quarrying in this district, which is unfortunately a rather remote quarter of the Island. Sample F.I. 61, from a short distance along the road to the Five Mile Lagoon district, is from a place very well suited to quarrying operations and in close proximity to a suitable road.

The quantity of stone available is large and much of it is of a friable nature so that it could easily be crushed. There are also smaller quantities of very tough stone suitable for road material, and massive stone that could be cut into blocks. Although not centrally placed with regard to the whole Island, it is one of the most accessible places to the eastern coastal plain where lime will be needed in great quantity when the area is opened up for settlement. This is one of the most suitable places on Flinders Island for a limestone quarry and the production of crushed lime.

Other sites suitable for quarrying operations exist in the Ranga district, particularly on the properties of P. Dart and J.A. Ferguson, but here the difficulty would be to secure a road into the quarry, passable in wet weather.

The grade of limestone also, is not as high as elsewhere, although a fair quality material is present in great quantity, and stone suitable for road making and building material is abundant. Limestone was crushed in this district some years ago on W.I. Martin's property, but the high grade secondarily enriched masses were selectively quarried, and these, although giving a very good agricultural lime, were correspondingly difficult to obtain and crush. It would be much more economical to work the more plentiful and easily processed limestones, although they may contain a somewhat lower percentage of carbonate of lime.

The large extent of limestone in the Lughrata district gave some samples of high grade limestone, but consistent good quality, combined with accessibility and a site suitable for quarrying was rare.

The three sites previously mentioned, namely, on the road to the Five Mile Lagoon district (Sample F.I. 61) near Whitemark School (Samples F.I. 1, F.I. 2, F.I. 13) and in the Ranga area (Samples F.I. 38, F.I. 37, F.I. 36, F.I. 51) can be recommended for further detailed sampling with the intention of opening up a quarry. The pits at Emita (Samples F.I. 31, F.I. 21), Lady Barron (Samples 1 - 6) and The Dutchman (Sample F.I. 55) are useful sources of unconsolidated limestone that can be worked for local use as agricultural lime without installation of crushing machinery.

<u>Summary and Conclusion</u>:

The investigation has shown that Flinders Island, which is the largest of a chain of islands in geological continuity from North Eastern Tasmania to Wilson's Promontory, is a reëmergent granitic platform, with eroded remnants of Palaeozoic sediments, bearing an Upper Pliocene to Recent formation over five hundred feet in thickness. This formation begins with shallow water, sandy sediments and passes up into deeper water calcareous deposits, with a few small, interbedded basalt flows.

The economic problem is, essentially, to produce some degree of intermingling of the calcareous and sandy sediments, separated by the conditions of natural deposition, in order that a soil, suitable for grazing and agriculture can be obtained. Recommendations have been made for achieving this object by using the limestones as agricultural lime, and other useful purposes to which the different types of limestone may be put have been suggested.

B. A., A.A.I.M.M.

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