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1962/43

THE PETROLOGY OF THE CARBONATE ROCKS OF THE WESTERN UNDILLA BASIN

by

G.A. Brown

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CONTENTS

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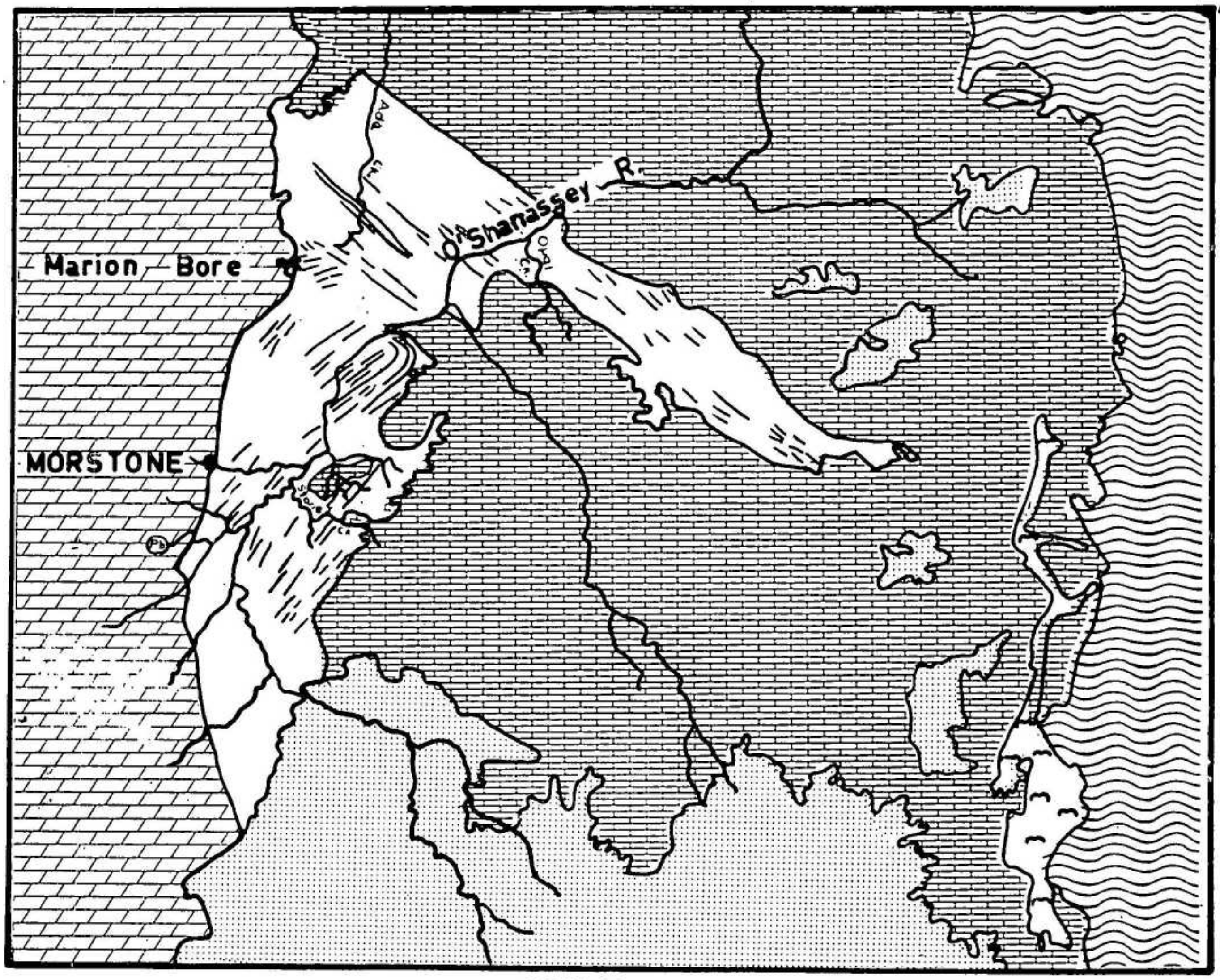
NOTE: This Record should be read in conjunction with Randal, M.A. and Brown, G.A. : "Additional Notes on the Geology of the Camooweal 4-Mile Sheet". Bur.Min.Resour.Aust.Rec. 1962/49 (unpubl.)

FIG. 1

SIMPLIFIED GEOLOGICAL MAP

of the

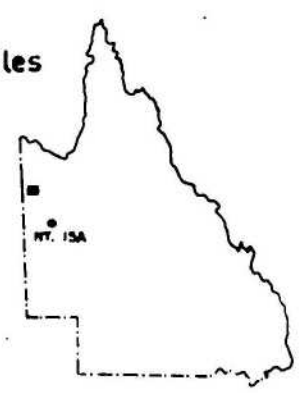
UNDILLA BASIN



SCALE

1 inch = 8 miles

0 8 16 24 32 miles



REFERENCE

RECENT	Alluvium
MESOZOIC	Undifferentiated
MIDDLE CAMBRIAN	Limestone sequence undifferentiated
	Age Creek Formation (with trend lines)
	Camooweal Dolomite
PRECAMBRIAN	Undifferentiated

Adapted from the Camooweal 4-Mile Geological Sheet E 54- 13

G.A.B.

THE PETROLOGY OF THE CARBONATE ROCKS OF THE WESTERN UNDILLA BASIN.

SUMMARY

The Camooweal Dolomite, Age Creek Formation, and V-Creek Limestone - Mail Change Limestone sequence of the western Undilla Basin are interfingering lateral equivalents. The Camooweal Dolomite is a fine-grained crystalline dolomite which interfingers with the pellet dolomites of the Age Creek Formation to the east. The Age Creek Formation interfingers eastwards with the oolitic pellet limestones of the V-Creek Limestone. This carbonate sequence represents a facies change from quiet, warm, shallow water evaporitic conditions in the west, through an area of strong, uni-directional currents depositing pellets in massive cross-beds of the Age Creek Formation, to shallow, warm water conditions in the east, where variable currents deposited detrital carbonate grains and also scoured pre-existing sediments.

INTRODUCTION

This Record contains the preliminary petrological results of a study of the dolomite facies in the Undilla Basin (Figure 1). Thin sections, and cut, etched and stained surfaces of rocks from the Camooweal Dolomite, Age Creek Formation, V-Creek, Mail Change and Thorntonia Limestones were examined.

LOCALITY

The Undilla Basin lies to the north and north-east of Camooweal in north-west Queensland, within the Camooweal Four-mile Sheet area. It contains a Middle Cambrian sequence of carbonate formations, and is bounded by the Precambrian Pilpah Range in the south, the O'Shanassey River in the north, and the Camooweal Dolomite in the west. The Precambrian metamorphic and granitic rocks of the Cloncurry - Mount Isa complex lie to the east.

RELATIONSHIPS

The Middle Cambrian formations of the Undilla Basin are described by Opik (1954, 1957 and 1960). Further field work carried out in 1961 has shown that formations on the western side of the basin are interfingering lateral equivalents, from the Camooweal Dolomite in the west, eastwards through the Age Creek Formation to the Mail Change Limestone - V-Creek Limestone sequence (Randal and Brown, 1962). As the formations investigated are generally unfossiliferous, they are distinguished by changes in lithology. The lithologies and environments of deposition of the formations are described.

SAMPLING

Relatively fresh, unaltered rock samples were collected from surface exposures on the western edge of the Undilla Basin. Each sample was sectioned by a diamond wheel, etched in acid, and examined in the field under a binocular microscope. Forty-three thin sections were prepared from selected specimens of dolomite and limestone.

TERMINOLOGY

The terminology used here does not strictly follow that set down by Condon (1953). It was found that the carbonate terms suggested by Condon were not suitable for distinguishing between the various carbonate rock types in this area. Some terms were felt to be **indefinite** as they had a genetic significance which was not in accordance with the origin of the rocks as observed in the field. An example is "dolarenite", which, if used in the same sense as calcarenite, would mean a rock formed from a sediment which originally consisted of sand-sized particles composed of dolomite. A dolomite sand, while perhaps conceivable in ancient sediments, is not known from Recent deposits. It is more conceivable that the sediment was composed of sand-sized calcite or aragonite particles and later dolomitised. In the present study, some rocks occur which appear to be dolarenites in the strict sense of the word, but there are other rocks which were almost certainly originally lime sands and which were dolomitised at a later date. Because of this confusion, a purely descriptive term is preferable, and "pellet dolomite" is used instead of dolarenite. "Pellet Limestone" is also a more useful field term than calcarenite. (See definition of "pellet" in the following section).

The terminology used is as follows :-

Authigenic : Minerals formed in situ in the sediment or rock by direct precipitation or replacement, at low temperatures prevailing at the earth's surface or at moderate depths within the crust (after Baskin, 1956).

Calcareous : Applies to rocks containing 10% to 50% $CaCO_3$.

Carbonate rock : A rock containing more than 50% carbonate minerals.

Cement : Used to denote mineral, usually carbonate, formed chemically between the grains of the sediment after deposition on the sea floor, and binding them together.

Clastic : A textural term used for a rock which shows evidence that the sediment was deposited mechanically, such as cross stratification or size sorting of particles.

Detrital : Made up of fragments of pre-existing rocks or sediments, not including contemporaneous organic deposits.

Diagenesis : The sum of the processes, with the exclusion of metamorphism, which lead to the transformation of an unconsolidated sediment into a compact rock, after the deposition of the sediment.

Dolomite : A sedimentary rock containing more than 50% of the minerals calcite (and aragonite) and dolomite (and ankerite) in which the mineral dolomite is more abundant than calcite.

Dolomitic limestone : Limestone in which the mineral dolomite is more than 10% and less than 50% of the combined calcite and dolomite.

Fragmental : Made up of fragments of other materials, such as shells, older limestones, or semi-consolidated sediments.

Limestone : A sedimentary rock containing more than 50% of the minerals calcite (and aragonite) and dolomite (and ankerite) in which the mineral calcite is more abundant than dolomite.

Matrix : Matrix is used here to denote any material deposited at the same time as larger grains by sedimentary methods. For example, lime mud matrix with shell fragments. Microcrystalline calcite, originally lime mud, is sometimes referred to simply as "matrix."

Mechanical : Applies to the process of deposition in which the particles of the sediment were brought to their place of final accumulation by agents such as water currents, wind currents, or gravity.

Oolite : A sedimentary rock made of spherules less than 2.0 mm. in diameter that show a concentric or radial structure or both. Oolite is also used for the individual spherules comprising the rock.

Oolitic : Rock containing oolites but not composed entirely of them.

Pellets : Rounded, spherical to elliptical bodies of carbonate material which have no regular internal structure and which have been formed within the basin of deposition. The term is used here to embrace both the "intraclasts" and faecal pellets of Folk (1959), and excludes oolites or spherulites. Pellets are generally darker in thin section than the surrounding cement or matrix due to a greater proportion of organic matter.

Pellet limestone, pellet dolomite etc. is used to denote a rock composed almost entirely of pellets (plus cement). Dolomite with pellets is used in the sense of a rock composed mainly of crystalline dolomite with scattered pellets "floating" in the dolomite matrix.

Terrigenous : Material derived from source lands outside the basin of deposition and transported as solids to the sediment (after Folk, 1959).

PETROLOGY

CAMOOWEAL DOLOMITE

Outcrops The Camooweal Dolomite generally crops out as flat benches or large rounded boulders, but occurs as 100 foot cliffs in the north-western part of the area. It is a white, buff, or mottled, usually thick bedded, fine-grained, laminated dolomite, which contains nodules and beds of white, brown or mottled chert.

Near the contact with the Age Creek Formation, the Camooweal Dolomite contains extensive cross lamination and scour-and-fill structures. These give way eastwards to large-scale foresets in the Age Creek Formation, in which no internal cross -lamination is present.

Petrology

In thin section, the Camooweal Dolomite varies considerably from a dolomite with pellets and intraformational pebbles, to a dense fine-grained crystalline dolomite. It also contains quartz, feldspar, and rare heavy minerals, forming up to 30% of the rock. The pellets in the Camooweal Dolomite are not always present, but are usually small, about 0.05 mm. in diameter, and similar in size to the terrigenous grains in the rocks. Towards the boundary with the Age Creek Formation, the size of the pellets increases, and larger pellets may incorporate the smaller ones.

According to Illing (1954) pellets are formed by the aggregation of minute carbonate mud particles (usually aragonite needles) on the sea floor. Transport by tidal currents and waves rounds the particles. The term pellet also includes faecal pellets, broken and rounded skeletal material, and eroded limestone fragments, whether of contemporaneous submarine origin or derived terrigenous origin. The pellets in the Camooweal Dolomite have probably been formed by aggregation of a calcium carbonate or dolomite mud. By aggregation of two or more pellets, "lumps or grapestone" (Illing, 1954) are formed. These are recognised in thin section as the "composite pellets" of the Age Creek Formation, and of the Camooweal Dolomite near its contact with the Age Creek Formation.

Fine-grained crystalline Camooweal Dolomite with pellets grades both laterally and vertically into the pellet dolomite of the Age Creek Formation. Away from the boundary, the Camooweal Dolomite is generally fine-grained or microcrystalline, but may be coarsely crystalline where some alteration has taken place. At C77, (Pb in Figure 1), large galena crystals up to several centimetres long are present in the rock (Plate 11, Figure 1). Here the dolomite is coarse-grained and contains voids filled with fibrous radiating dolomite crystals. The very fine-grained dolomites in places contain small ghost structures of recrystallised pellets. The intraformational pebble conglomerates contain long, flat, relatively thin pebbles of dark, very fine-grained dolomite, in a matrix of microcrystalline dolomite (Plate 1, Figure 2); pellets are not universally present. The terrigenous material in the Camooweal Dolomite is mainly quartz, with plagioclase, microcline and tourmaline (blue or green), which indicates derivation from a granitic area.

Environment

The overall very fine grainsize of the Camooweal Dolomite suggests that it was deposited as a carbonate mud under quiet conditions in shallow sea water. The laminate nature of the rocks suggests deposition below wave base in an area of gentle currents. The existence of intraformational pebble conglomerates suggests the breakup of semi-consolidated carbonate mud by storm waves in shallow water. The deposition of a large area of carbonate mud such as represented by the Camooweal Dolomite suggests a warm climate, and a shallow sea, connected to an open ocean which maintains a constant inflow of sea water saturated with $CaCO_3$. The origin of the dolomite is a problem which cannot be resolved at present. It is possible that the dolomite was precipitated directly onto the sea floor, as a dolomite mud, but it could also be the result of dolomitisation of an original lime mud. This latter theory may be preferable, in the absence of conclusive evidence for the deposition of pure dolomite mud. It is generally considered that dolomite is formed by the reaction of sea water with calcite or aragonite just below the sediment interface, in an area of shallow, warm seas, which is subject to very slow rates of subsidence, and extensive reworking of the sediment. Cloud and Barnes (1957, p.183-185) conclude that dolomitisation is a process which can occur penecontemporaneously with the deposition of the sediment, that sea water is the source of the magnesium, and that dolomitisation is favoured by shallow, warm waters and long exposure of the sediment on or near the sea floor. This does not disagree in any way with the observed features of the depositional environment of the Camooweal Dolomite. No areas of widespread deposition of pure dolomite mud are known from Recent deposits. However, the possibility of the direct precipitation of dolomite mud from sea water in the Precambrian and Lower Palaeozoic cannot be dismissed, because atmospheric conditions may have changed, especially the CO_2 pressures, which must have been different during the absence of land plants. Conditions possibly existed which. although completely unknown at the present day, favoured the precipitation of magnesium, rather than calcium carbonate to maintain natural equilibria.

AGE CREEK FORMATION

Outcrops

The Age Creek Formation interfingers with the Camooweal Dolomite and crops out as rough karst structures, deeply incised by creeks and rivers, to the east of the Camooweal Dolomite. In surface outcrop it is white or buff, with large pellets visible on the weathered and fresh surfaces. It weathers to jagged, collapsed blocks which are usually black on exposed surfaces. It is mainly a dolomite composed of large pellets, oolites, algal material, fossil fragments and terrigenous material. It is often very porous, the porosity being of the intergranular type, due to the large grains being generally cemented only at the points of contact.

Petrology

The carbonate grains in the Age Creek Formation are pellets, oolites, and algal particles. The pellets are well rounded and usually slightly flattened. They may be composed of dark microcrystalline dolomite; paler, slightly more coarsely crystalline dolomite; smaller pellets, oolites and fossils in a dark matrix (i.e. composite pellets). Less common are pellets composed of quartz and feldspar of terrigenous or authigenic origin in a microcrystalline matrix; or dark algal material, which may have irregular algal banding, or may be crowded with algal filaments. Pellets may be over 2.0 mm. in diameter, and are generally more than 0.1 mm. in diameter. The composite pellets are made of smaller dark pellets generally about 0.05 mm. in diameter. Some small composite pellets are themselves incorporated in composite pellets showing that the sediment had undergone several periods of deposition and erosion.

Approximately 50% of the rocks examined from the Age Creek Formation contain oolites which are all recrystallised by dolomitisation (Plate 6, Figure 2). Few of them retain their oolitic structures; some have a visible pellet or quartz sand grain core, and some have darker bands which reveal an original concentric structure. In very rare cases, a core surrounded by a laminated shell is still visible. Mostly, however, the oolite is expressed, in thin section, by a circular arrangement of dolomite crystals, which may be slightly darker (and finer grained) than the surrounding dolomite cement (Plate 7, Figure 1)

In some rocks the dolomite crystals of the recrystallised oolites are arranged radially and the oolite ghosts can be seen plainly in polarised light. The average grainsize of the oolites is 0.3 mm. They are well sorted, and are remarkably even in size, both within a single specimen, and from locality to locality.

Carbonate spherulites are rare in the Age Creek Formation; they are mostly confined to the cores of oolites or the interiors of composite pellets. In some samples many of the oolites are worn, broken or crushed. The oolitic rocks seldom contain large quantities of pellets, although most samples contain some pellets. However, in some oolitic samples, the oolites are subordinate to the pellets. These samples usually contain considerable amounts of quartz and chert, as well as derived carbonate pellets, suggesting an accumulation of particles from different source areas (Plate2, Plate 3). The oolites are normally in contact (Plate 6, Figure 1), and cemented by radiating dolomite crystals only at the points of contact. Many of the oolitic rocks are therefore very porous. This is also true for some of the coarse pellet dolomites (Plate 4, Figure 2). Oolites in which most of the porespace has been destroyed by the formation of a dolomite crystal mosaic are also present (Plate 6, Figure 2).

Very few samples show any evidence of compaction, such as broken oolites, oolites dissolved at the points of contact, or deformed oolites; in most cases cementation has taken place before compaction has occurred. The cement is therefore an early diagenetic product, and appears to be of two types. The first type is a relatively coarse mosaic of dolomite crystals, which appears to be a recrystallised or dolomitised original calcareous earlier cement. The second type consists of dolomite rhombs growing into the spaces between the large dolomite pellets (Plate 4, Figure 2). This appears to be a primary cement as the crystals are euhedral; they are growing with their "c" axes perpendicular to the grain surfaces, after the manner of primary diagenetic sparry calcite cement, and the crystals do not completely fill the spaces between the grains. These could represent true "dolarenites". The mechanism for the deposition of primary dolomite cement in a detrital sand is not known.

Very few of the pellet dolomites have a fine-grained matrix which has the appearance of a primary lime or dolomite mud. The only pellet rocks within the Age Creek Formation which have a lime mud matrix are those composed of algal grains. These rocks occur as limestone layers up to several inches thick within the dolomites. The algal grains vary from algal "dust" to 2.0 mm. in diameter, and are concentrically laminated, red or brown, irregular shaped particles. The larger particles are generally cemented by sparry calcite, but concentrations of the smaller algal particles are generally surrounded by a dark algal mud. It appears that the larger particles grew in an environment of stronger currents, which were able to winnow out the smaller particles and lime mud.

Lenses of thin bedded, flat-lying, fossiliferous dolomite and dolomitic limestone occur within the foresets of the Age Creek Formation. They represent very fine-grained carbonate mud deposits. They were probably formed when the foresets built up to a flat topped delta type of structure. The strong currents producing the foresets would flow down each side of the "delta" and carbonate mud deposits would be formed in the quieter shallow waters on top of the "delta". When the level of the surrounding pellet sediment reached the level of the top of the "delta", massive foresets would again be built over the whole area.

The quiet environment on top of the "delta" was favourable for the growth of brachiopods, the phosphatic shells of which are preserved in the dolomite. Trilobites also lived in these areas, and some trilobite fragments are preserved. However, their presence is more often indicated by trilobite tracks on the bedding planes. The sediment has been recrystallised and may also represent a lime mud which has been dolomitised. It appears in thin section as a fine-grained dolomite mosaic. Small pellets, organic fragments, algal grains and spherulites are seen to be "floating" in the fine-grained matrix. The fact that the grains are not in contact shows that the currents in the area were not strong enough to winnow out the fine carbonate mud. The pellets and other grains are all small, and probably formed <u>in situ</u>.

<u>Terrigenous material</u> is almost universal in the pellet dolomites, but less common in the fine-grained thin bedded rocks of the fossiliferous lenses. Two distinct grainsize groups of terrigenous material can be distinguished in thin sections; a coarse grade, with grains larger than 0.1 mm. diameter, and a finer grade, with grains of 0.05 mm. or less. A statistical count of the terrigenous material has not been carried out, and no numerical grainsize distribution results can be presented. The coarser terrigenous material is confined to the western margin of the Age Creek Formation near Marion Bore in the north, but in the south about Bauhinia Creek it spreads out to the east. The smaller terrigenous grains are almost universal throughout the Age Creek Formation, and show no apparent areal distribution. The large quartz grains are well rounded, spherical, contain sillimanite (?) needles and rows of bubbles and have an undulose extinction which is evidence of strain. Some grains are made up of smaller interlocking crystals, suggesting derivation from a metamorphic quartzite. Smaller, angular terrigenous grains with an average grainsize of about 0.05 mm. are common in some samples, making up to 30% of the rock. This terrigenous material consists of unstrained quartz, plagioclase, microcline, tourmaline, zircon, hypersthene, and garnet or spinel. The heavy minerals are usually well rounded, but the quartz and feldspar are often angular.

Overgrowths on the quartz and feldspar are common, being almost universal on the larger quartz grains (over 0.1 mm.). Two periods of overgrowths separated by abrasion are present in some samples. Embayment of the quartz due to replacement by carbonate is relatively common. In some cases the smaller quartz grains are pitted and the grains of feldspar are enlarged. The larger strained quartz grains often contain peculiar herringbone shaped fractures which suggest that strain may have been imposed on the quartz in the sedimentary rock and is not a product of an igneous or metamorphic environment (see Appendix I).

Chert grains of terrigenous origin are common in the north around Ada Creek, sometimes making up 100% of the terrigenous material. They are usually the same size or slightly smaller than the pellets in the rock, and appear as grey grains in the hand specimen. The chert grains are usually well rounded, but a few are angular. Many show evidence of replacement by carbonate from the edges inwards, and some contain minute brown carbonate rhombs, suggesting derivation from a pre-existing silicified limestone. The chert in the Camooweal Dolomite adjacent to the Ada Creek area is white or brown, not grey like the chert grains in the Age Creek Formation. These chert grains would probably have come from the same direction as the other terrigenous material in the area, that is from the north-east, as suggested by the strike and dips of the foresets. It is considered unlikely that the chert grains are a product of the replacement of carbonate pellets in situ as many grains show no signs of carbonate inclusions, the edges are sharp, and the carbonate inclusions that are present in some of the chert grains, are euhedral crystals, which are not present in the surrounding rock. Some grains are replaced around the edges by clear anhedral carbonate. In one sample in which some pellets have been replaced by chert, the chert is brownish and chalcedonic, with colloform structures, and is entirely different to the detrital variety. The former is probably due to surface silicification. (Chert - see Plate 10)

Environment

The environment of deposition of the Age Creek Formation appears to be one of strong currents, causing the massive foresets seen in the field, carrying coarse terrigenous material from the north-east, transporting coarse pellets, and winnowing out any carbonate mud. Carbonate mud may be deposited directly from the sea water, formed from the abrasion of the pellets, or deposited by algae. Shallow water is indicated by the widespread occurrence of oolites, and the area must have been sinking slowly and steadily to allow for the development of the large foresets.

Some areas were built up above the general level of the pellet sediment to form small "deltas", and in the shallow quiet water on top of these areas carbonate mud was deposited. Brachiopods and trilobites were preserved in these sediments.

LIMESTONE SEQUENCE (See Figure 1).

The limestones described below occur as lenses and fingers along the eastern margin of the Age Creek Formation. They are shown on the published Camooweal 4-mile Geological map as Mail Change Limestone, but field investigations suggest that they are lithologically similar to the V-Creek Limestone (Opik, 1954; Opik, 1960). Opik (personal communication) agrees with this view, but considers that there is a thin veneer of Mail Change Limestone overlying the exposures. The limestones occur along Stoney Creek, between Stoney Creek and Corkwood Creek, and along the O'Shannassey River. The V Creek Limestone interfingers with the Age Creek Formation, but Opik considers the Mail Change Limestone is higher in the sequence, and overlies both the V-Creek and the Age Creek Formations. These relationships are further discussed in Randal and Brown (1962).

Outcrops

In outcrop the V-Creek Limestone is a grey, buff or white, laminated, usually thin bedded limestone, dolomitic limestone, or dolomite. It may be microcrystalline, or contain pellets, oolites, terrigenous material, authigenic marcasite or pyrite, and fossils (brachiopods, and trilobites).

The Mail Change Limestone is brown, red or buff and grey mottled and occurs mainly to the east, although thin beds of it are seen in the north along the O'Shannassey River. It is typically thick bedded, massive and fine-grained.

Petrology

In thin section the V-Creek Limestone typically contains pellets, oolites and terrigenous material. Fossil fragments are present in some specimens. Laminations, including graded bedding, can be seen in most thin sections. The pellets show a great variety of internal structures, many being composite or containing terrigenous material. The composite pellets often contain smaller pellets, oolites and spherulites (which may be worn or broken) and algal material. Many pellets are composed of dolomite. Individual oolites are 0.3 mm. in diameter, and are generally better preserved than those in the Age Creek Formation. Mostly they are still calcite, and have a core, and an outer shell with concentric laminations. Many are recrystallised into a single crystal or into several large crystals with the "c" axes radially disposed. In all cases, broken and eroded oolites are present. The core may be a pellet, spherulite, or sand grain, but many cores are obliterated by recrystallisation. Where oolites are present, the cement is generally composed of calcite crystals with the "c" axes perpendicular to the surfaces of the grains. Some oolites occur in areas of lime mud, and in most cases this matrix is optically very dense and appears to be of algal origin. Some areas of the thin sections are crowded with algal filaments (Girvanella), giving a "spaghetti" effect to the groundmass.

A common feature in the thin sections of the V-Creek Limestone is the evidence for submarine erosion in the sediment. The laminae of the rocks are caused by the deposition of different sediment types on the erosional surfaces. A typical laminate specimen consists of two distinct sharply defined layers.

The lower layer consists of dark (algal?) microcrystalline calcite with 30% terrigenous material (quartz, feldspar, tourmaline, zircon, hypersthene), pellets, oolites and spherulites up to 0.15 mm. diameter. The spherulites consist of a large carbonate core with a shell containing fibrous radial calcite crystals and have grown in situ in the matrix as many of them incorporate quartz grains in their shells. The feldspar has overgrowths with carbonate inclusions, some forming euhedral feldspar crystals. The quartz is pitted and corroded by carbonates. The layer includes authigenic marcasite crystal aggregates up to 5.0 mm. diameter. Some areas of the layer contain matted algal fibres suggesting an algal origin for the matrix. Broken and worn oolites are present. Towards the top of the layer, pellets become smaller and more common, and oolites become rarer.

The overlying layer contains over 50% quartz, feldspar, muscovite (common), hypersthene and garnet, in a groundmass of fine dolomite rhombs. The quartz is strongly pitted and the feldspar has overgrowths. The differences between these layers illustrates a change in the conditions of sedimentation, and in the source of the sedimentary grains. This type of change is common in the laminate rocks of the V-Creek Limestone. Eroded oolites and pellets are common at laminae interfaces, showing that strong currents eroded semi-consolidated sediments.

Some of the limestone lithologies contain fossils, which are seen in thin sections. In general, those fossils which are preserved in limestone have calcareous shells and those which have been preserved in dolomite have phosphatic (collophanite) shells. The dolomites in the sequence contain composite pellets, oolites, shell fragments and sometimes terrigenous material in a fine-grained dolomite matrix. Some samples have alternate microcrystalline dolomite and pellet layers. They have similar sedimentary structures to the limestones.

Environment

The environment of deposition of the V-Creek Limestone was one of strong currents, variable in direction, depositing sediment from several different source areas, and reworking the sediment previously deposited. The currents were strong enough to erode the surface of semi-consolidated sediments and carry the reworked particles to other areas of deposition. At certain times conditions were favourable for the growth, and later preservation, of marine organisms. Some of the sediment was deposited as a chemical or algal carbonate mud. Reducing conditions prevailed below the water-sediment interface in some areas to allow the formation of marcasite and pyrite. Some of the sediments were dolomitised after deposition, such as those containing oolites, but some may have been deposited originally as dolomite. Evidence for the deposition of primary dolomite, or the very early dolomitisation of the sediments in one of the formations in the area, is seen in the presence of dolomite pellets and calcite pellets in a limestone. The dolomite pellets were probably washed in from an area of either primary dolomite deposition or early diagenetic dolomitisation. The water was generally shallow to allow for the formation of oolites and the growth of algal mats.

CONCLUSIONS

From this study the environments of the Camooweal Dolomite, the Age Creek Formation, and the limestone sequence change from west to east. In the area of the Camooweal Dolomite in the west, the water was shallow, warm, and relatively free from strong current or wave action, except for occasional disturbances due to storms. The Age Creek Formation was deposited in an area of strong, uni-directional currents, less tectonically stable than that of the Comooweal Dolomite, and with a mainly external supply of sediment. The V-Creek Limestone was deposited in a warm, shallow sea which was subject to strong eroding currents of variable direction, in an area of both carbonate precipitation and external sediment source. The significance of these environments is discussed in Randal and Brown (1962).

PHOTOMICROGRAPHS

All photomicrographs have been taken in normal transmitted light unless otherwise stated.

All photomicrographs x 32.

The number reference (e.g. M/197/7/20Av130) after each photomicrograph represents the following :

M/197 is the B.M.R. photographer's reference number

7 is the film number

20 is the frame number of the negative on film No.7

Av130 is the field reference number

PLATE 1.

Figure 1 : Camooweal Dolomite from the central part of the Barkly Tableland on Avon Downs Sheet. Intraformational pebbles, pellets and spherulites in fine-grained dolomite matrix.

M/197/7/20/Av130

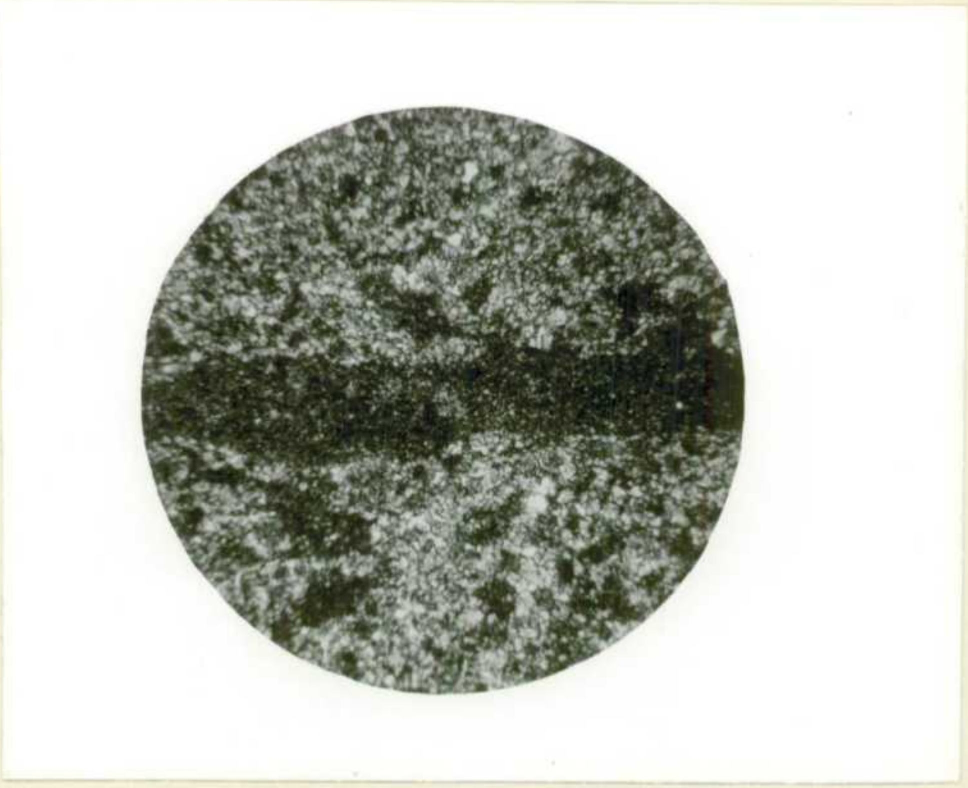


Figure 2 : Camooweal Dolomite from Avon Downs Sheet with intraformational pebbles in a dark fine-grained dolomite matrix.

M/197/7/17/Av129

PLATE 2

AGE CREEK FORMATION.

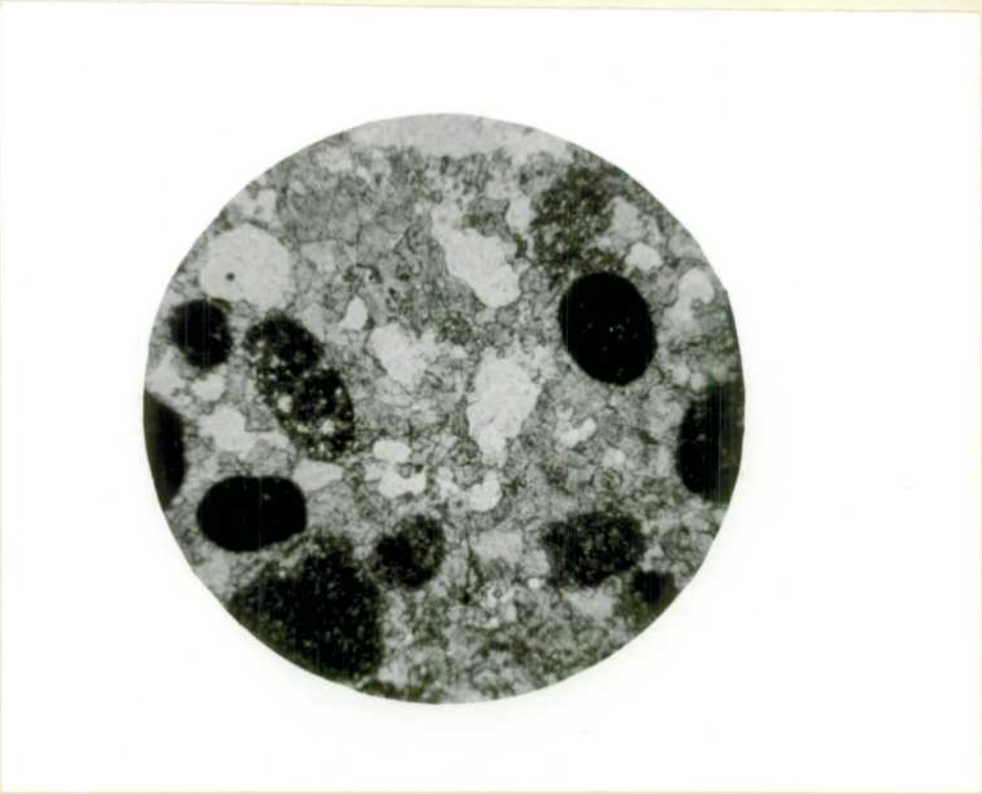


Figure 1 : Composite pellets (dark) in a crystalline dolomite matrix which probably represents recrystallised pellets. The light areas are porespace which makes up 20% of the rock.

M/197/5/23/C15

Figure 2 : Composite pellets in a fine-grained crystalline dolomite matrix. This rock is much less porous than that shown in Figure 1.

M/197/5/27/C28

PLATE 3

AGE CREEK FORMATION

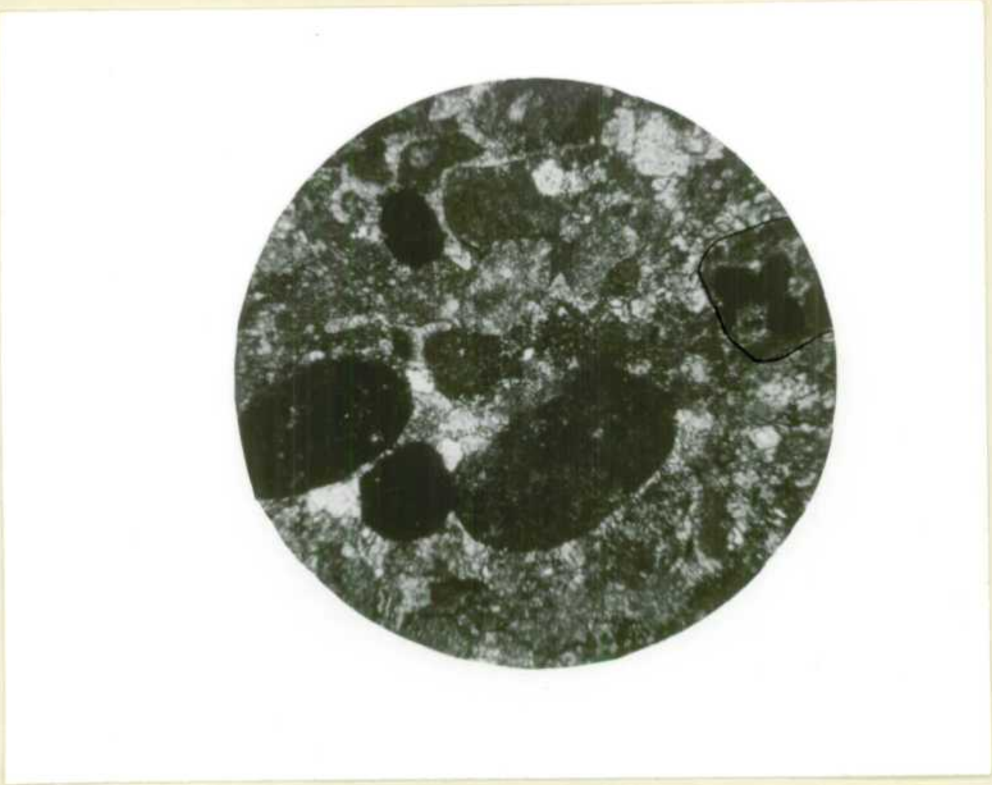


Figure 1 : Coarse pellet dolomite. Note the composite pellet on the right-hand border (outlined).

M/197/6/23/C166

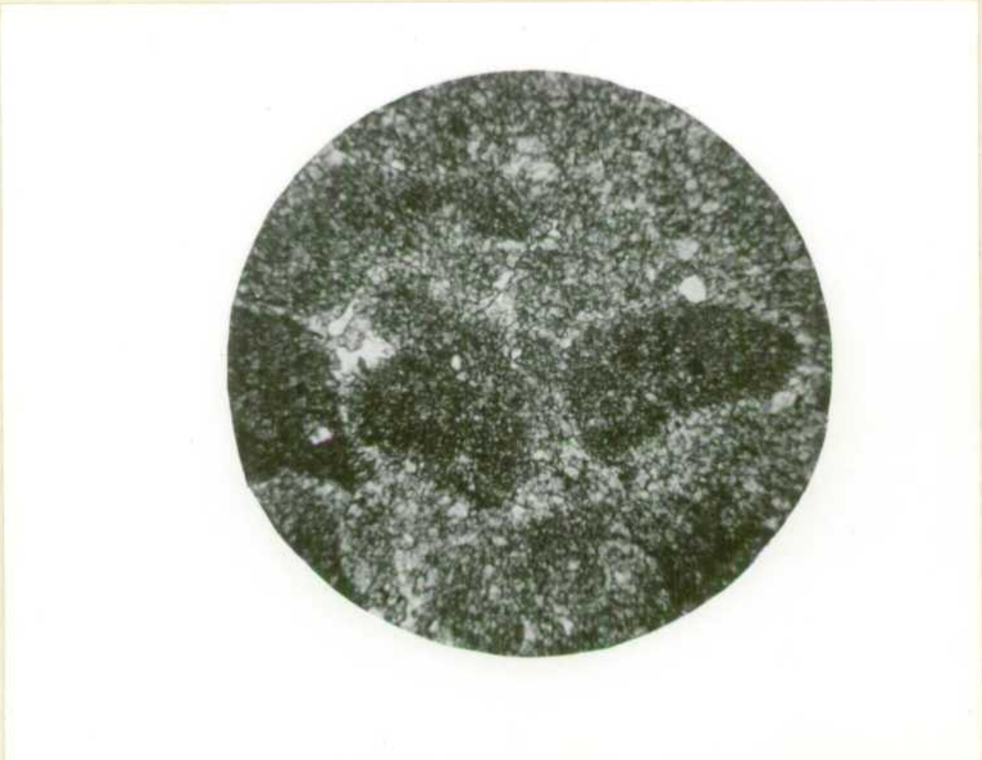


Figure 2 : Coarse pellet dolomite, recrystallised into a fine dolomite mosaic, with only pellet ghosts left.

M/197/6/8/C76

PLATE 4

AGE CREEK FORMATION

Figure 1 : Very coarse pellet dolomite from the Age Creek Formation. The pellets are composite and are cemented with probable primary dolomite.

M/197/6/2/C58

Figure 2 : Very coarse pellet dolomite from the Age Creek Formation. The pellets are cemented at the points of contact only, leaving voids (light areas) between the grains.

M/197/6/14/C118

PLATE 5

AGE CREEK FORMATION

Figure 1 : Coarse pellet dolomite cemented only at the points of contact of the pellets, leaving large open pores (light areas).

M/197/6/20/C162

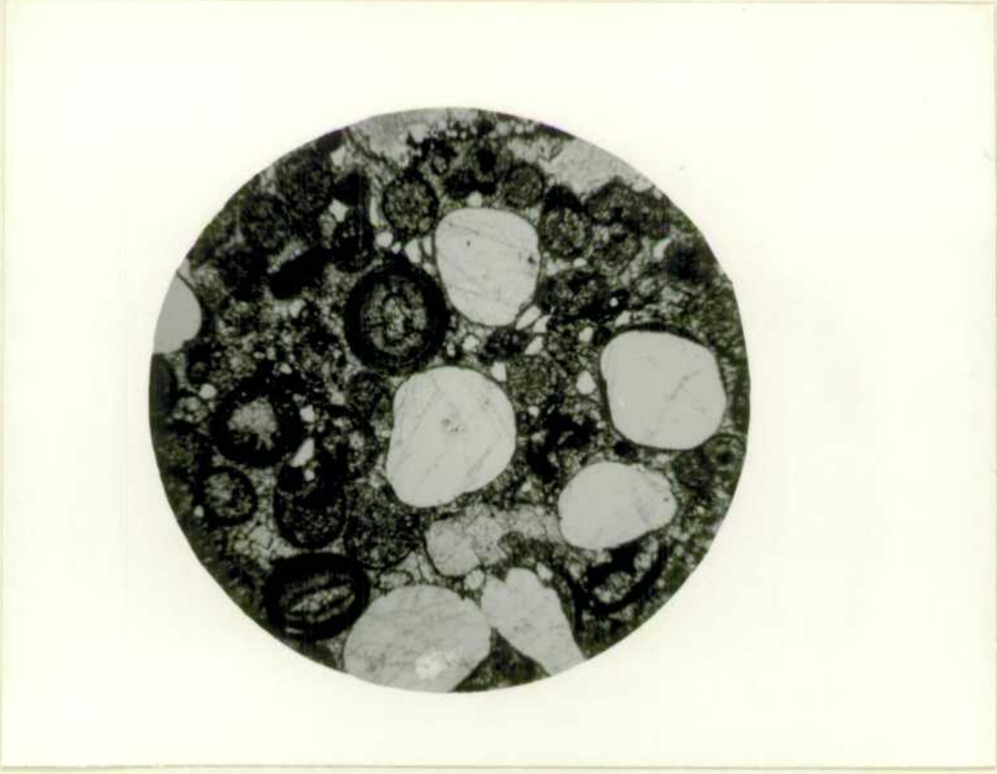


Figure 2 : Oolitic dolomite with coarse and fine grades of terrigenous quartz sand grains.

M/197/6/7/C67

PLATE 6.

AGE CREEK FORMATION

Figure 1 : Oolites and fine terrigenous material in a fine-grained dolomite matrix. The oolites are recrystallised and dolomitised, and some are crushed and dissolved due to compaction. The cores of the oolites are pellets or quartz sand grains.

M/197/6/5/C67

Figure 2 : Recrystallised oolites, coarse and fine-grained terrigenous matter, and pellets in a crystalline dolomite matrix.

M/197/6/30/C172

PLATE 7

AGE CREEK FORMATION

Figure 1 : Dolomitised oolite, with many of the oolites recrystallised leaving a coarse dolomite mosaic. Some, e.g. the dark grain near the centre of the photomicrograph, recrystallise to a fine-grained dolomite mosaic. M/197/6/29/C169B

Figure 2 : Pellet dolomite cemented by primary(?) euhedral dolomite crystals, leaving open voids between the pellets (crossed nicols). The pellets are mostly recrystallised.

M/197/5/16/C106.

PLATE 8.

AGE CREEK FORMATION

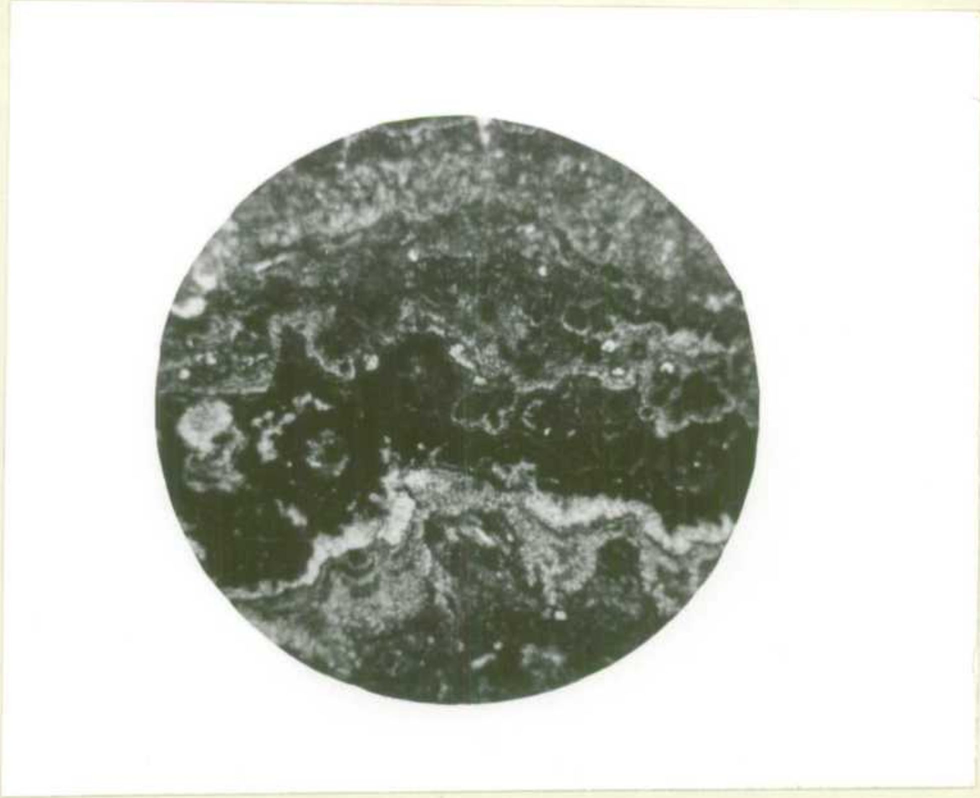


Figure 1.: Algal deposits of a limestone interbed in the dolomites of the Age Creek Formation. The deposit has a colloform structure of dark microcrystalline to finely crystalline calcite, with coarser calcite crystals filling voids.

M/197/6/28/C169A

Figure 2 : Algal deposits of a limestone interbed in the dolomites of the Age Creek Formation; polarised light. The deposit is layered dark microcrystalline calcite, with calcite crystals filling elongate voids in the sediment.

M/197/6/27/C169A

PLATE 9.

AGE CREEK FORMATION

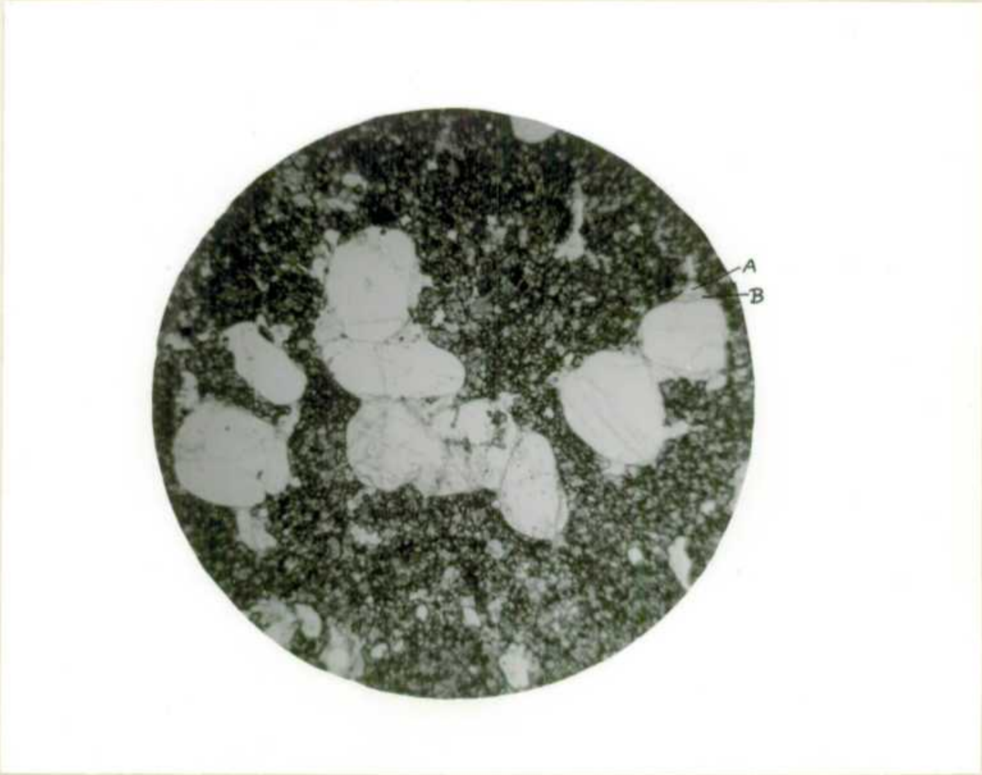


Figure 1 : Large quartz grains with two periods of overgrowths on some (A and B) in a fine-grained dolomite groundmass. Note the distinctive pattern of the inclusions (bubbles) in the quartz grains.

M/197/5/25/C21

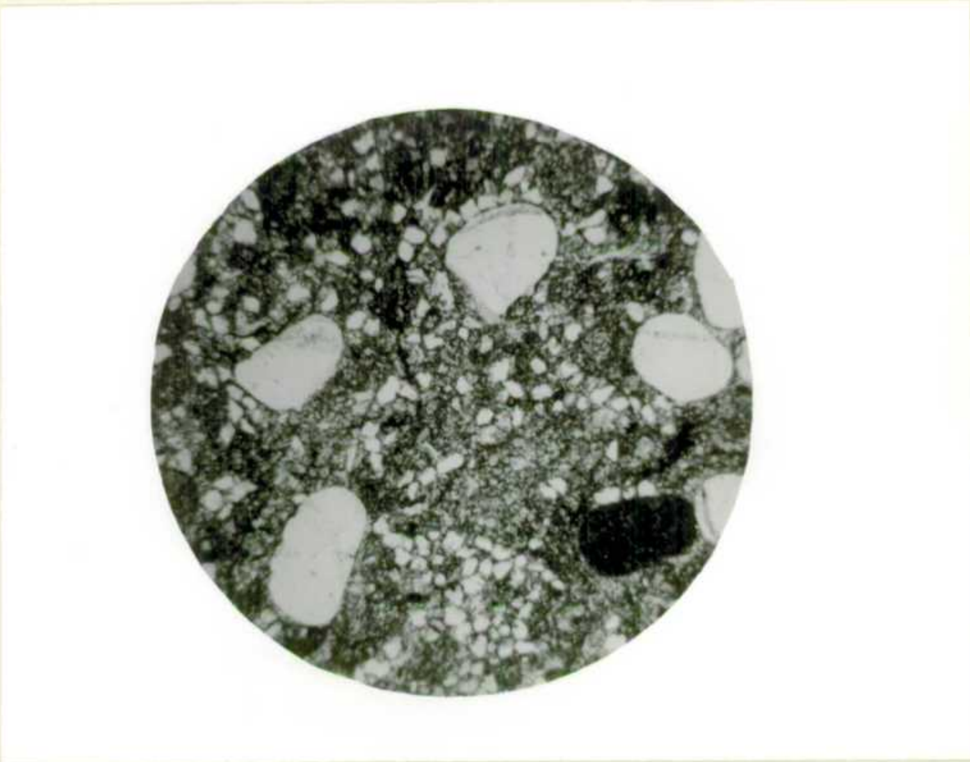


Figure 2 : Large rounded quartz grains with overgrowths in a matrix of fine-grained dolomite and fine terrigenous matter, with large pellets and pellet ghosts scattered throughout.

M/197/5/17/C108

PLATE 10.

AGE CREEK FORMATION

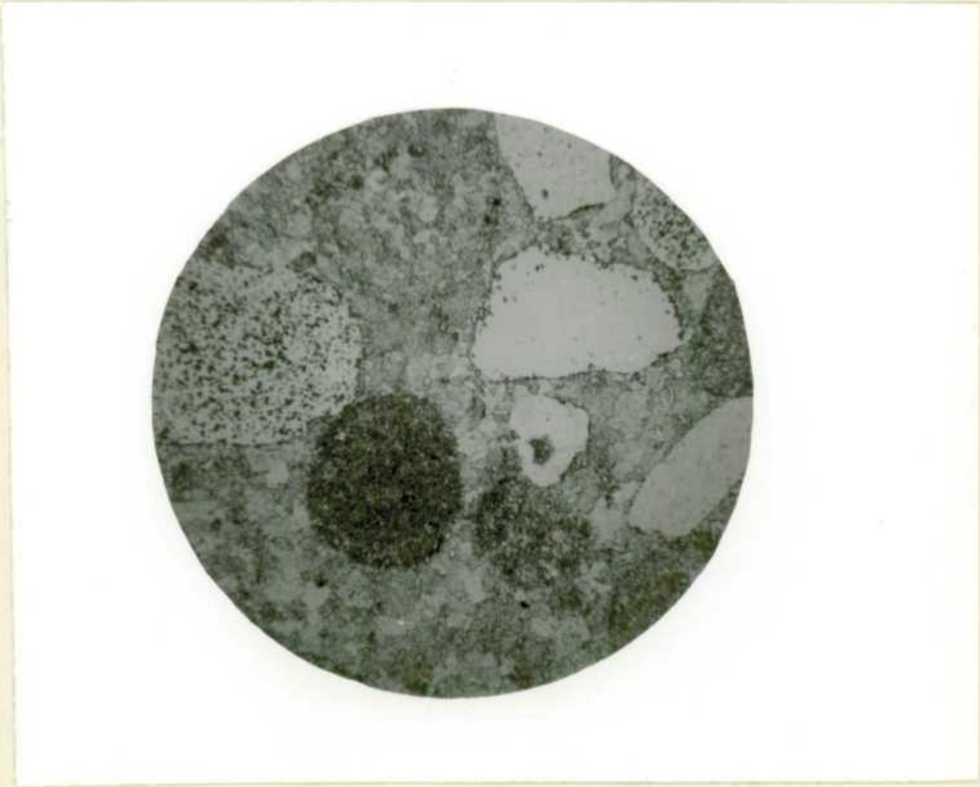


Figure 1 : Large detrital chert grains (grey) in a recrystallised pellet dolomite. Note the dark inclusions of euhedral carbonate crystals in the light-coloured chert grains.

M/197/5/36/C43/7

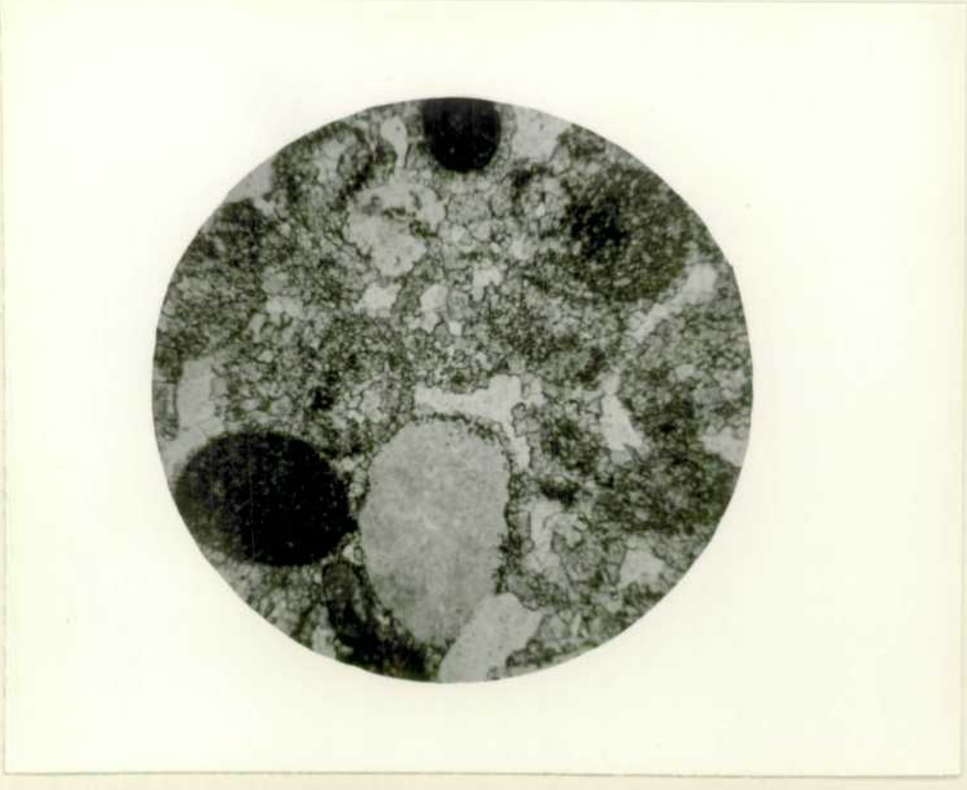


Figure 2 : Chert grain (grey) in a pellet dolomite. Note that some pellets are recrystallised and are now seen only as a dolomite crystal mosaic. The cement appears to be primary dolomite, and euhedral dolomite crystals can be seen surrounding all grains and projecting into voids between them.

M/197/6/3/C59

PLATE 11.
SULPHIDES IN THE CARBONATE ROCKS

Figure 1 : Large galena crystals in coarsely crystalline (recrystallised) Camooweal Dolomite, Totts Creek.

M/197/5/21/C77

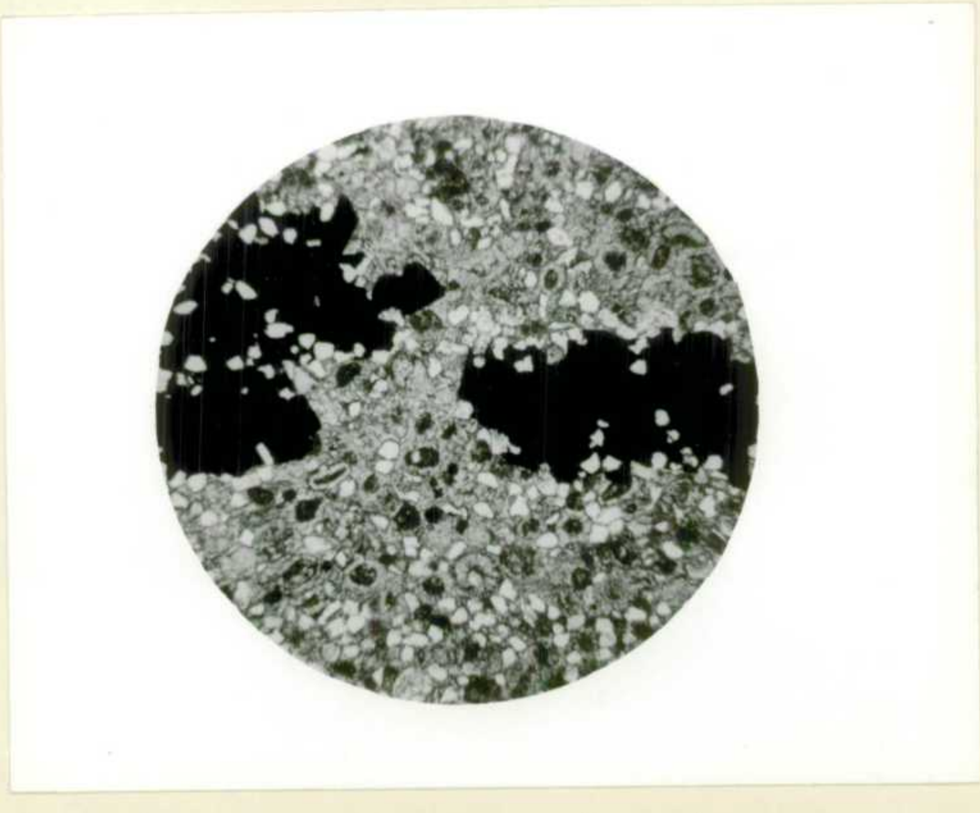


Figure 2 : Marcasite crystal aggregates (black) in dolomitic limestone containing pellets, oolites and fine terrigenous material, in a finely crystalline calcite matrix. The marcasite crystal aggregates have grown in situ as shown by the concentration of terrigenous material within them. V-Creek Limestone, Stoney Creek area. M/197/5/11/C2

PLATE 12

V-CREEK LIMESTONE

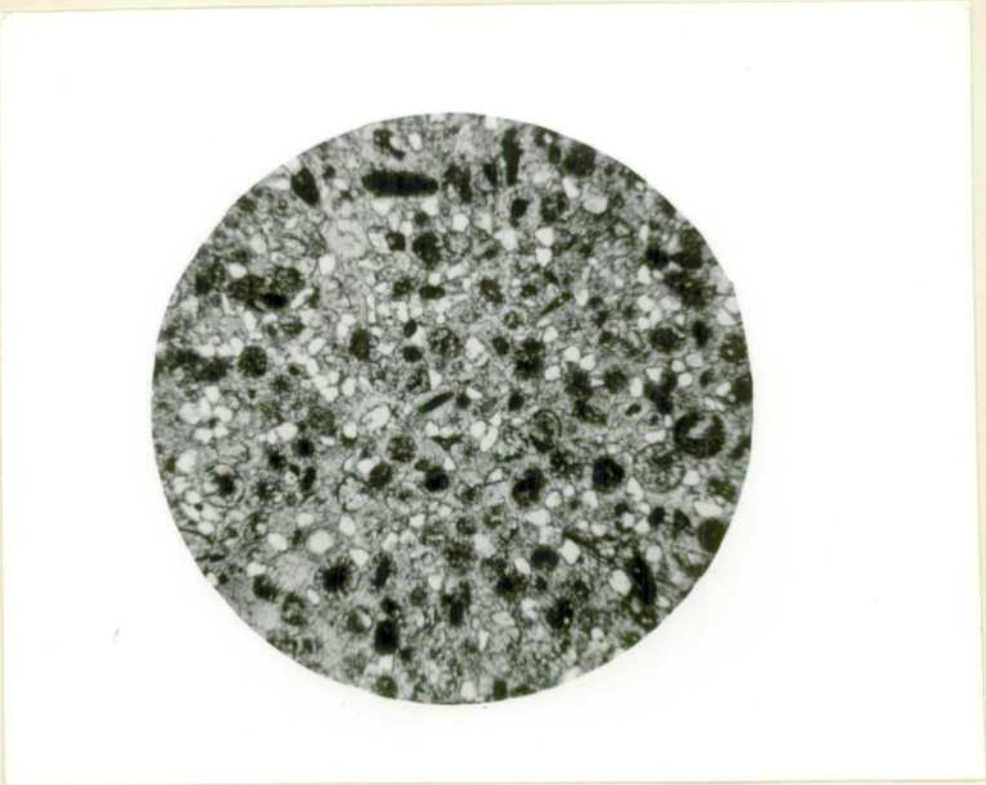


Figure 1 : V-Creek Limestone containing small pellets and oolites and fine terrigenous material.

M/197/5/9/C2

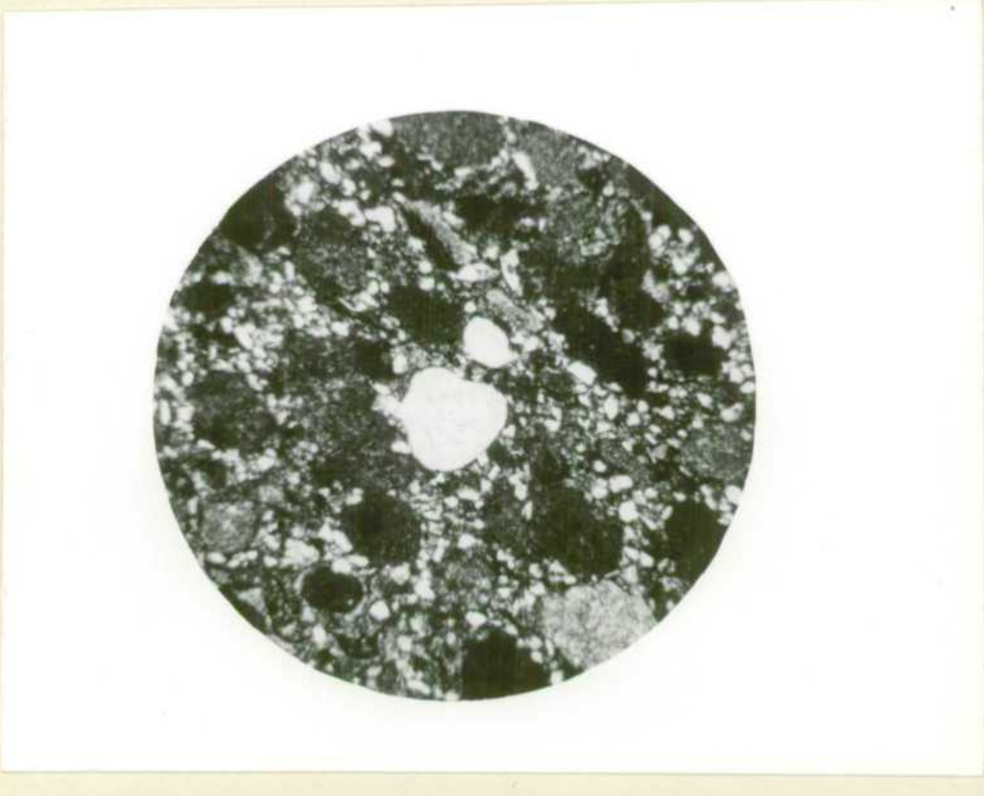


Figure 2 : V-Creek Limestone containing coarse pellets, and coarse and fine grades of terrigenous material.

M/197/5/7/C4

PLATE 13

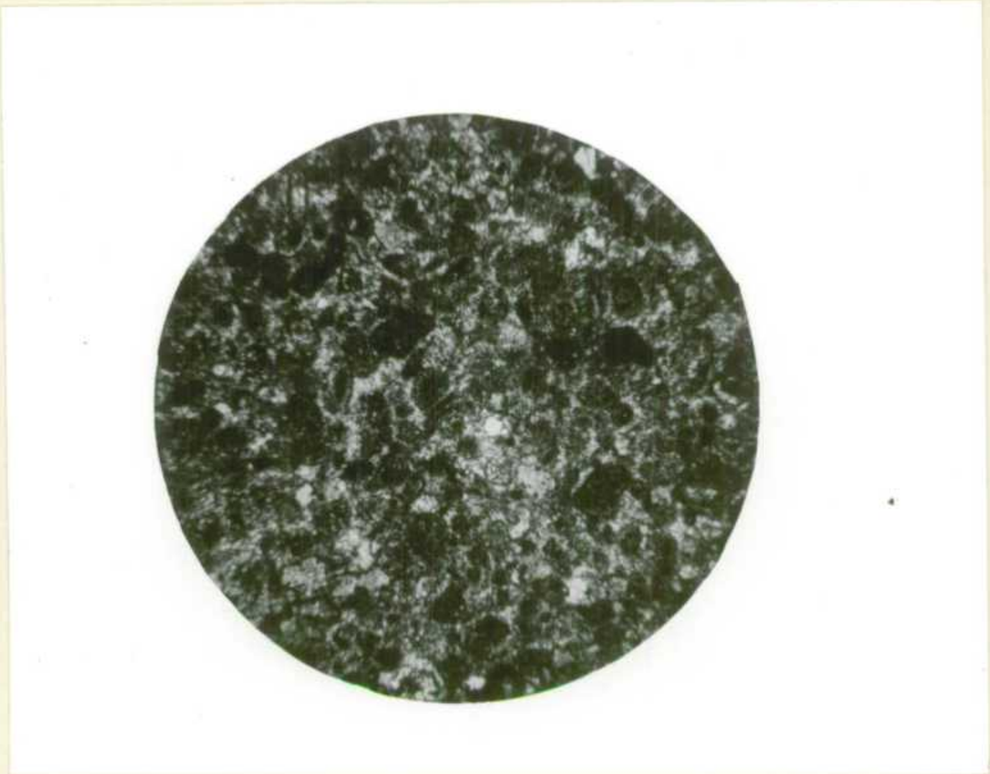


Figure 1 : Mail Change Limestone: buff-grey mottled calcilutite in outcrop. Contains pellets, shell fragments and algal filaments in thin section. Mottling is due to dolomite rhombs. Photomicrograph shows small pellets in a fine-grained calcite matrix.

M/197/6/34/C181

Figure 2 : White crystalline dolomite from Marion Creek, mapped as Thorntonia Limestone.

M/197/5/29/C36-1

APPENDIX I.

FEATHER FRACTURE IN QUARTZ GRAINS.

In many of the thin sections containing coarse (greater than 0.1 mm. diameter) quartz grains, the quartz shows evidence of strain in the form of undulose extinction in cross polarised light. Some of these grains also have a peculiar herringbone or feather shaped fracture pattern passing through them. This pattern is a continuation of a single, minute fracture through the dolomite mosaic of the matrix of the rock. In many thin sections the fractures occur in several grains, and in these cases the fractures are parallel throughout the thin section.

The fractures consist of curved fractures which diverge from a central straight axis (Plate 15). Major fractures diverging from the axis are joined to the axis by minor curved fractures concave towards the apex of the diverging fractures. Major fractures often do not join across the axis but are connected by the cross-fractures. The major fractures are often open, but very few open minor fractures were observed.

Feather-fracture in homogeneous rocks from the South Wales Coalfield have been described by Roberts (1961). His conclusions are as follows :-

(a) Feather patterns occur upon fracture surface (joints) in rocks.

(b) The feather patterns are controlled by lithology - some rock types inhibit their development. Homogeneity and grainsize play an important part.

(c) Feather development is apparently restricted to shear joint surfaces, since it has seldom been recorded on fractures attributed to a tectonic, tensional force.

(d) The feather patterns are themselves a fundamental mode of rock fracture, analogous to "cleavage fracture" in steel.

(e) The suggested "cleavage" nature of feathered joint surfaces .....explains the lack of evidence of horizontal movement along shear joints.

The above conclusions suggest that the development of feather fractures in the Age Creek Formation, even on a microscopic scale, indicates that the area has been subjected to shearing stresses. This is further supported by <u>en echelon</u> joints, folds and faults in some areas. The development of the feather fractures only in the quartz grains is probably due to the homogeneity of the quartz. It was not developed in the carbonate matrix because of the heterogeneous nature of the dolomite crystal aggregate, and probably because the grainsize of the matrix was either too large, or too large in comparison with the crystal structure of the quartz. In the carbonate matrix, any lateral movements due to the shearing has been accommodated by recrystallisation or cleavage plane slip, but in the quartz crystals it has been accommodated by the feather fracture. Other quartz grains which do not have the feather fractures usually show effects of strain in undulose extinction in cross polarised light.

PLATE 14

Feather fracture in a large (1.0 mm.) quartz grain, with a grain showing strain effects (undulose extinction) on the ~~left.~~ right The rock was originally a coarse pellet sediment with 5% quartz, cemented only at the points of contact of the grains. It was later recrystallised, so that the carbonate pellets are now mosaics of fine dolomite crystals. The rounded black area at the ~~top~~ bottom is a quartz grain in extinction; the irregular black areas are voids between the original carbonate pellets.

Crossed nicols. From the Age Creek Formation.

M/197/6/9/C74

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