PLATE 5

(a) "Brick-like"-texture at the top, with coarse-grained anhedral dolomite at the bottom, displaying a "chevron"-texture. The contact between them is quite sharp. From Slide A80. (Crossed polars).

(b) Dolomicrite, with a dolosparite-filled stromotactoid, in the Upper Dark Dolomite Zone. The cavity is diffuse and elougated in the horizontal direction. The base is flattened, whilst the top is digitate. From Slide A65. (Plane polarized light).

(c) Bladed, length-slow chalcedony, displaying zoned extinction. From Slide A115. (Crossed polars).

(d) Rounded, speroidal shapes outlined by dusty, carbonaceous material, set in a siliceous matrix. Note the radial fabric (bottom right) on the outer part of the structure which may represent replaced aragonite. From Slide A91. (Crossed polars).

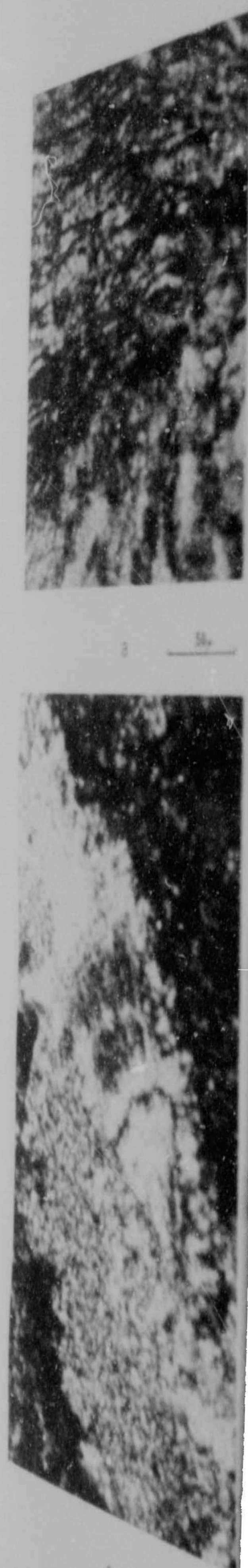
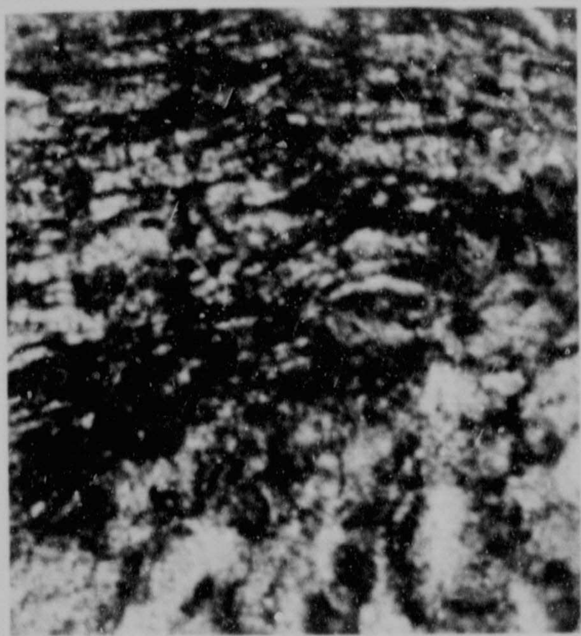
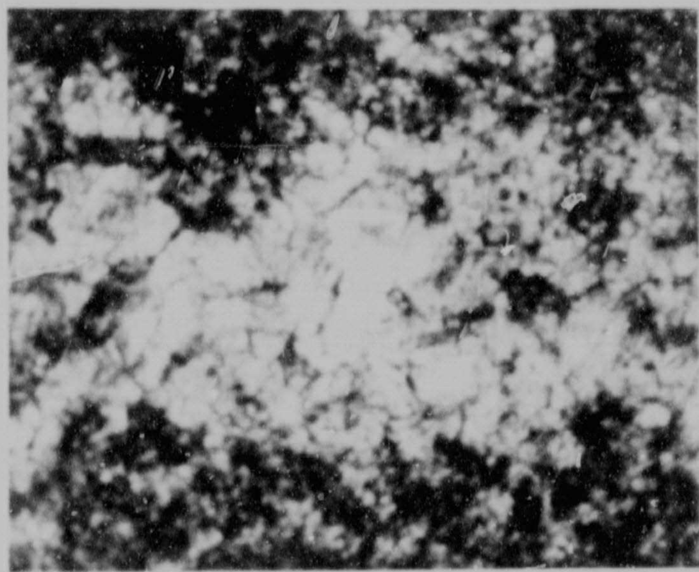


PLATE 5



a 50μ



b 50μ

c 50μ

d 50μ

thinning of the Intimately-Mixed Zone in Borehole UD30 is mirrored by an increased thickness in the chert breccia and reflects down-cutting of the palaeokarst surface. Eriksson (1971) suggested that the chert breccia thickened over antiformal structures which appears to be the case in this situation.

Texturally, this zone is distinct and consists of cream-coloured dolomicrite, intimately-mixed with laminae, or fenestrae, of translucent, cryptocrystalline silica (Plate 6b). The chert forms irregular patches, discontinuous thin layers, and bands up to 50 centimetres in width. Primary structures and fabrics are well preserved, and length-slow chalcedony spherulites are present in many chert samples. In thin-section, dolomicrite is the major component of these rocks, with minor dolosparite. Small fenestrae, approximately 1 millimetre long and 0,2 millimetres wide, are filled with fine-grained silica, but are rimmed with dolosparite and coarsely-crystalline dolomite. These fenestrae are indicative of an early porosity, created during the dissolution of algal remains. Stromotactoids are common, and these structures are infilted with dolosparite and chert. The difference between stromotactoid and fenestral structures lies in the fact that the former display digitate upper surfaces, whereas the latter do not.

Ooids occur in numerous thin bands, generally less than 20 centimetres thick, and frequently exhibit an increase in ooid diameter upwards. They are invariably overlain by fine-laminated dolomicrite, and this represents a fining-upwards, or shallowing-upwards, cycle (Plate 6d). The ooids are more common towards the top of the zone and are partly or wholly silicified. Concentric and radial fabrics are often preserved and a variety of ooid textures have been identified:

(i) dolomicritic ooids enclosed in a dolosparite matrix;
(ii) silicified ooids set in a dolosparite matrix;
(iii) silicified ooids set in a siliceous or carbonaceous matrix, and
(iv) dolomicritic ooids cemented by silica.

These types of ooids were also recognized by Eriksson (1971). Oncoids associated with oolitic horizons are quite common and are mostly subrounded, ranging in diameter from 2 to 5 centimetres. Several flattened oncoids, up to 5 centimetres in length, have been observed (Plate 6c), similar to those described by Hofmann (1974). Many of the laminae have been silicified. Thin, flat-pebble breccias are present throughout the sequence, and, in many cases, lie immediately above flat, laminated dolomite-and-chert. Intraclasts are normally less than 3 centimetres in length, and some appear to have been silicified prior to transportation (Plate 6e). Intercalated within the Intimately-Mixed Dolomite-and-Chert Zone are several mottled dolomite horizons. These display a distinctive texture (Plate 6c) and consist of grey dolomicrite, randomly peppered with white dolomite patches, set in a translucent silica matrix. In thin-section (Plate 5d), the fabric consists of spheroidal shapes outlined by dusty, black, carbonaceous material. The sphere-margins coalesce and may represent unicells, similar to those detected by MacGregor (1978). The mottled zones are often composed of stromotactoids, filled with white, coarsely-crystalline dolomite, and are chert-poor. Several of the mottled horizons correlate throughout the area and may indicate relict evaporites. Dark, chert-poor dolomite horizons and carbonaceous mudstones are present, but are not common. The latter form thin bands, less than 5 centimetres in width.

Stromatolites are ubiquitous in this zone and are mostly of the domal, laminated, laterally-linked variety. These structures are similar to types d,e,f,g,h, and i illustrated in Figure 21. The structures are partially, or wholly, replaced by silica, but the coarser dolosparite crystals, together with carbonaceous dust, are less susceptible to replacement and form thin laminae, outlining the original stromatolite structure. The contacts between chert bands and dolomicrite are very sharp macroscopically, but, in thin-section, are slightly diffuse. Palisade textures are common, and the fibrous, feathery nature of each palisade is preserved in chert bands, possibly because the fibrous dolomite is less prone to recrystallization. Stromatolite laminae may be crinkled or planar, and the domes are frequently interbedded with finely-laminated, intimately-mixed dolomite-and-chert.

White dolomite veins, which occur sporadically throughout this zone, occasionally carry massive pyrite and are often associated with brecciated material. Pyrite is observed as small cubes, or amorphous grains, in many parts of this zone and is randomly distributed.

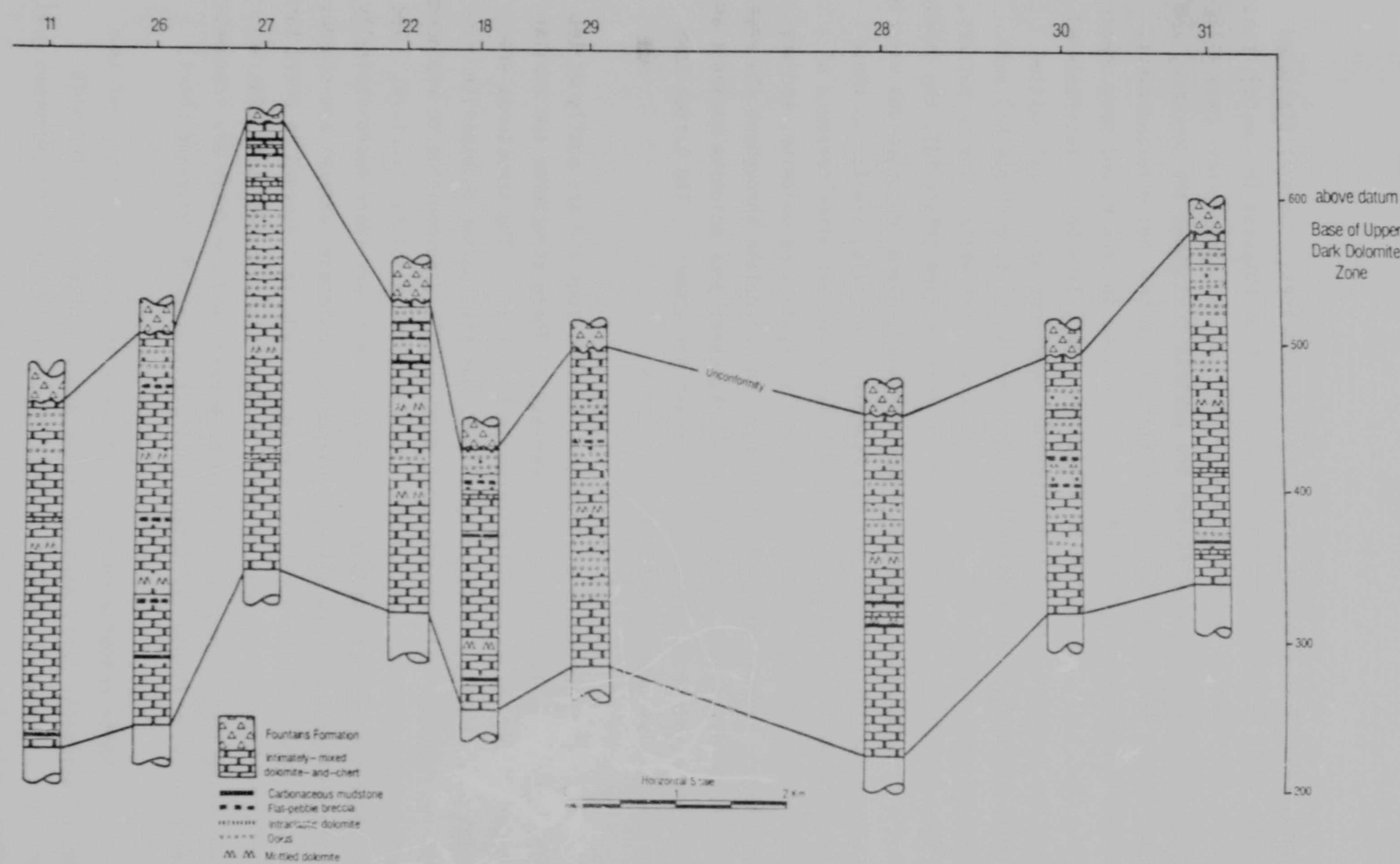


Figure 40 : A panel-diagram illustrating the lateral variation of the Intimately-Mixed Dolomite-and-Chert Zone.

PLATE 6

(a) Columnar stromatolites in the Upper Dark Dolomite Zone. The columns are linked, partly branched, and set in a dolomicrite matrix. Note the development of stromotactoids between the columns, which are filled with coarsely-crystalline, white dolomite. From Sample A65, Borehole UD18, depth 870 metres. ($^1/_2$ natural size).

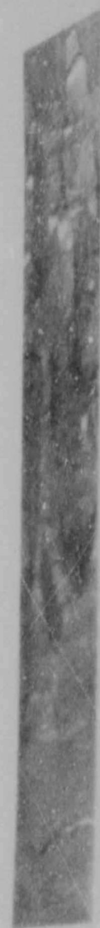
(b) Typical intimately-mixed dolomite-and-chert. The chert does not form distinctive layers and is pervasive. Stromatolite laminae are present, but it is difficult to estimate the size and nature of the stromatolite, because of the limited view presented in core-samples. From Sample A82, Borehole UD27, depth 925 metres. ($^1/_2$ natural size).

(c) Flattened oncoid developed within a fining-upward cycle of ooids. Note the coarser ooids near the base. Most ooids are partly recrystallized to dolosparite. From Sample A73, Borehole UD28, depth 609 metres. (Natural size).

(d) Fining-upward sequences within the Intimately-Mixed Dolomite-and-Chert Zone. From Sample A37, Borehole UD28, depth 609 metres. (Natural size).

(e) Flat-pebble breccia, partly silicified, developed above the stromatolite, showing palisade structures. The silicified intraclasts are generally subrounded and display geopetal textures. Ooids are present at the top of the photograph. From Sample A98, Borehole UD24, depth 650 metres. (Natural size).

(f) Distinctive, mottled dolomite-and-chert horizon from within the Intimately-Mixed Dolomite-and-Chert Zone. In thin-section, the rounded shapes are similar to the spheres in Plate 5d. From Sample A91, Borehole UD25, depth 517 metres ($^1/_3$ natural size).



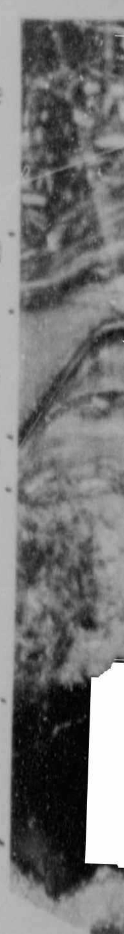
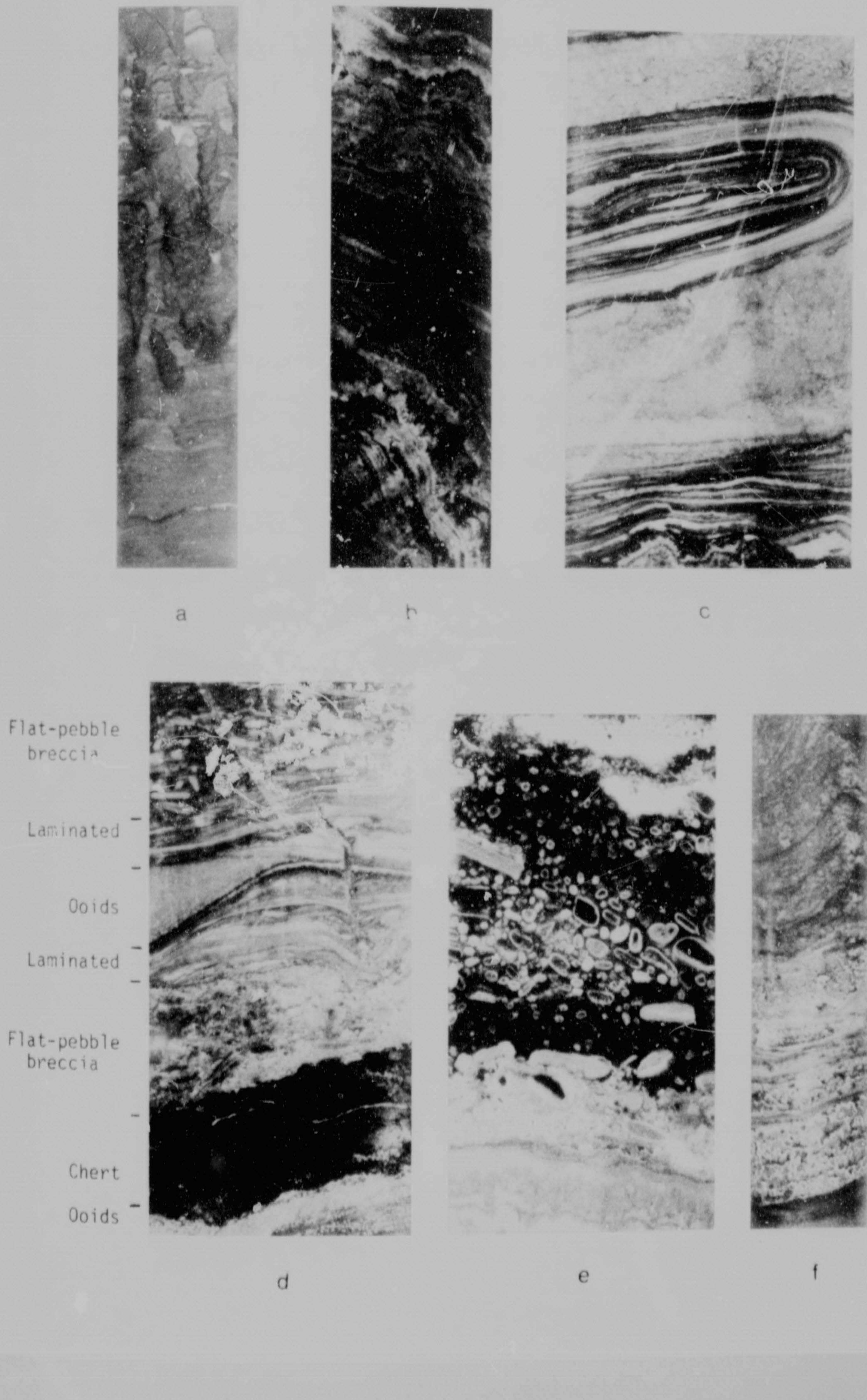


PLATE 6


a
b
c
Flat-pebble breccia
Laminated
Ooids
Laminated
Flat-pebble breccia
Chert
Ooids
d
e
f

2. Sedimentology

Sedimentary structures in this zone include abundant stromotactoids, ooids, flat-pebble breccias, oncoids, and shallowing-upward cycles, similar to those recognized in the Complex Dolomite Zone. These structures are largely indicative of shallow-marine conditions. Evidence, such as teepee structures and dessication cracks, were not discerned, but length-slow chalcedony spherulites, fenestrae, and stromotactoids do indicate dessication (Wilson, 1975). The mottled zones may represent replaced evaporites, and the shallowing-upward cycles, with ooids at the base and laminated dolomite-and-chert at the top, suggest build-up of the sediment to extremely shallow depths. There are many similarities with the Complex Dolomite Zone, but an important difference is that, in this zone, extremely coarsely-crystalline dolomite is absent. If sedimentation was of a similar style, then certain diagenetic processes were active in the Complex Dolomite Zone which did not operate in the Intimately-Mixed Zone. The reason for this is unclear, but if an evaporative reflux model is invoked as the mechanism responsible for dolomitization, then it is likely that this did not function in this zone, in this area. The panel-diagram (Figure 40), illustrates the lateral correlation of this zone and the isopach data indicates the presence of a north-trending synform, on the Elandsrand property, and a north-trending, north-plunging antiform in the east, both of which were active during sedimentation.

M. HISTORY OF DOLOMITIZATION AND SILICIFICATION

1. Introduction

In the Malmani dolomite, there are textures which have important genetic implications with respect to the dolomitization and silicification processes. In the past, the origin of the mineral dolomite has always been a matter of conjecture in sedimentary geology, and it has generally been considered to be a product of the replacement of limestones. In the study-area, there are no limestones, which indicates that either calcium carbonate was not generated during sedimentation or that the dolomitization process was completely effective and altered all primary limestones. Numerous theories have been proposed to explain the mode of origin of dolomite, but it is only with the discovery of Recent and modern dolomite that any progress in understanding these rocks has been made.

Dolomites have been recognised in arid and semi-arid climates, and these are particularly associated with water evaporated to the point where gypsum is precipitated. Consequently, as gypsum is removed from sea water, the Mg^{2+}/Ca^{2+} ratio increases, and the alteration of $CaCO_3$ to $CaMg(CO_3)_2$ is favoured. Primary dolomite consists of crystals less than 3 microns in size, and this is analogous to micritic muds forming in the Bahamas. These primary dolomites are similar in lithology to the dark dolomicrites of the Malmani dolomite, although it cannot be concluded with any certainty that the dark dolomicrites are primary in origin. However, as these dark zones are frequently, laterallv persistent, it is possible that they represent distinct episodes of dolomicrite precipitation.

2. Chemical considerations for the formation of dolomite

The precipitation of calcium carbonate from an aqueous medium is dependent upon several chemical equilibria. At the solid-liquid interface of $CaCO_3$ in a solution, the following equilibrium equation is important:

$$CaCO_{3(s)} = Ca^{2+}_{(aq)} + CO^{2-}_{(aq)} \qquad [1]$$

and the solubility product in $\left[Ca^{2+}_{(aq)}\right] \cdot \left[CO^{2-}_{(aq)}\right]$. In an aqueous solution, equilibria which affect the disolution or precipitation of $CaCO_3$ are:

$$CO_{2(aq)} + H_2O_{(1)} = H_2CO_{3(s)} \qquad [2]$$

$$H_2CO_{3(s)} = H^+_{(aq)} + HCO_3^-{}_{(aq)} \qquad [3]$$

and, in the presence of free CO_3^{2-} ions, the H^+ ions react further:

$$H^+_{(aq)} + CO^{2-}_{3(aq)} = HCO^-_{3(aq)} \qquad [4]$$

and more bicarbonate is formed. The above equilibria may be displaced in either direction, depending upon which components are added or removed from the system, and these four equations can be summarized into equation [5]:

$$CO_{2(aq)} + H_2O_{(l)} + CaCO_{3(s)} = Ca^{2+}_{(aq)} + 2HCO^-_{3(aq)} \qquad [5]$$

At pH values greater than seven, as in sea water (≈ 8), the equilibrium in equation [5] moves to the left, and $CaCO_3$ is precipitated. It has been shown (Sass, 1965) that sea water is supersaturated with calcite above 16°C and dolomite above 28°C, so that dolomite should precipitate above 28°C. However, if there is a high $CaCO_3$ content, the first carbonate mineral phase to appear is invariably aragonite, but, at approximately 25°C and 1 atmosphere pressure, calcite is the more stable mineral (Clark, 1957) (Figure 41).

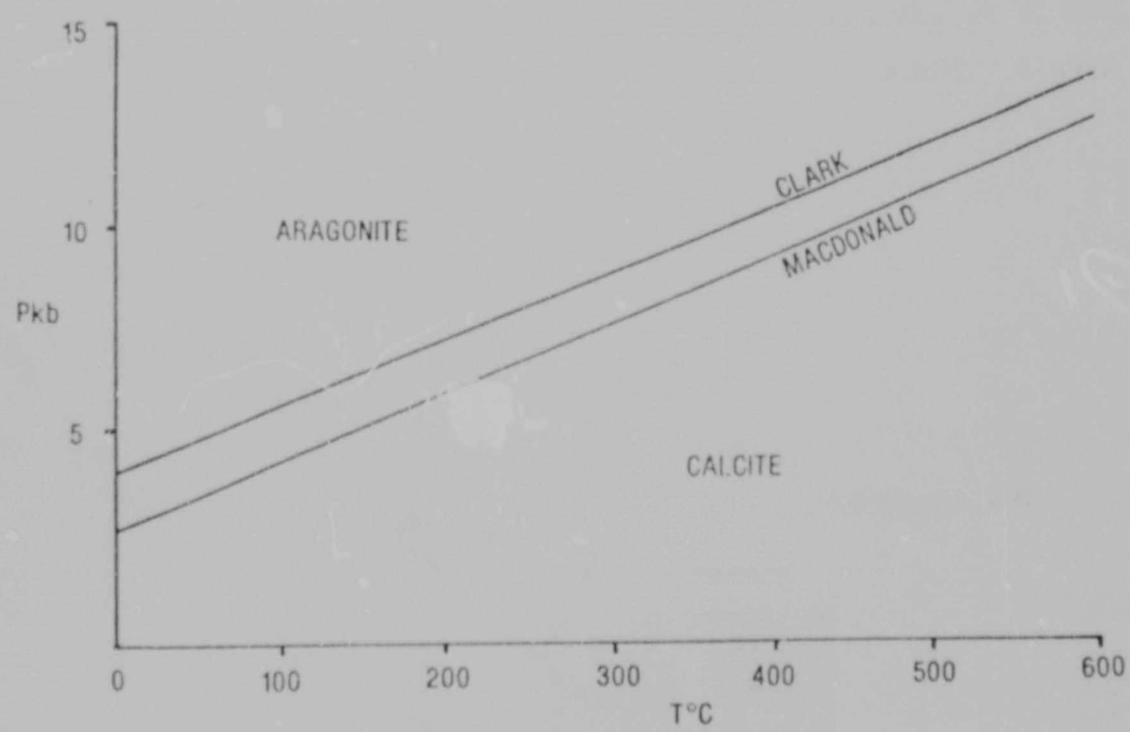


Figure 41 : A diagram illustrating the stability fields for calcite and aragonite under differing temperature and pressure conditions.

In fact aragonite is metastable and, during diagenesis, inverts to calcite, consequently aragonite is rarely preserved in ancient carbonates. In the Malmani dolomite it is interesting to note that, in several samples, fabrics reminiscent of aragonite were detected and are similar to modern aragonite textures. It is apparent therefore, that at least some of the dolomites were originally aragonitic.

The mechanism of dolomite precipitation was considered by Liebermann (1967) to be a two-stage process:

(i) dissolution of $CaCO_3$ in sea water; and

(ii) $CaCO_3$ and $MgCO_3$ precipitated together.

It was suggested that, in shallow marine conditions, (i) would take place at night, when temperature and pH are relatively low and CO_2 high. This condition is created during the respiration period of photosynthesizing organisms. Stage (ii) should occur when daytime temperatures and pH are higher and CO_2 partial pressure is low, as for instance during metabolic, active photosynthesis. Liebermann (1967) concluded, after conducting several experiments, that dolomite should precipitate from solution and that in sea water, this happens at 4-6 times normal salinity, when the pH is between 8 and 9, and when $CaSO_4$ and CO_2 have been effectively removed. Figure 42

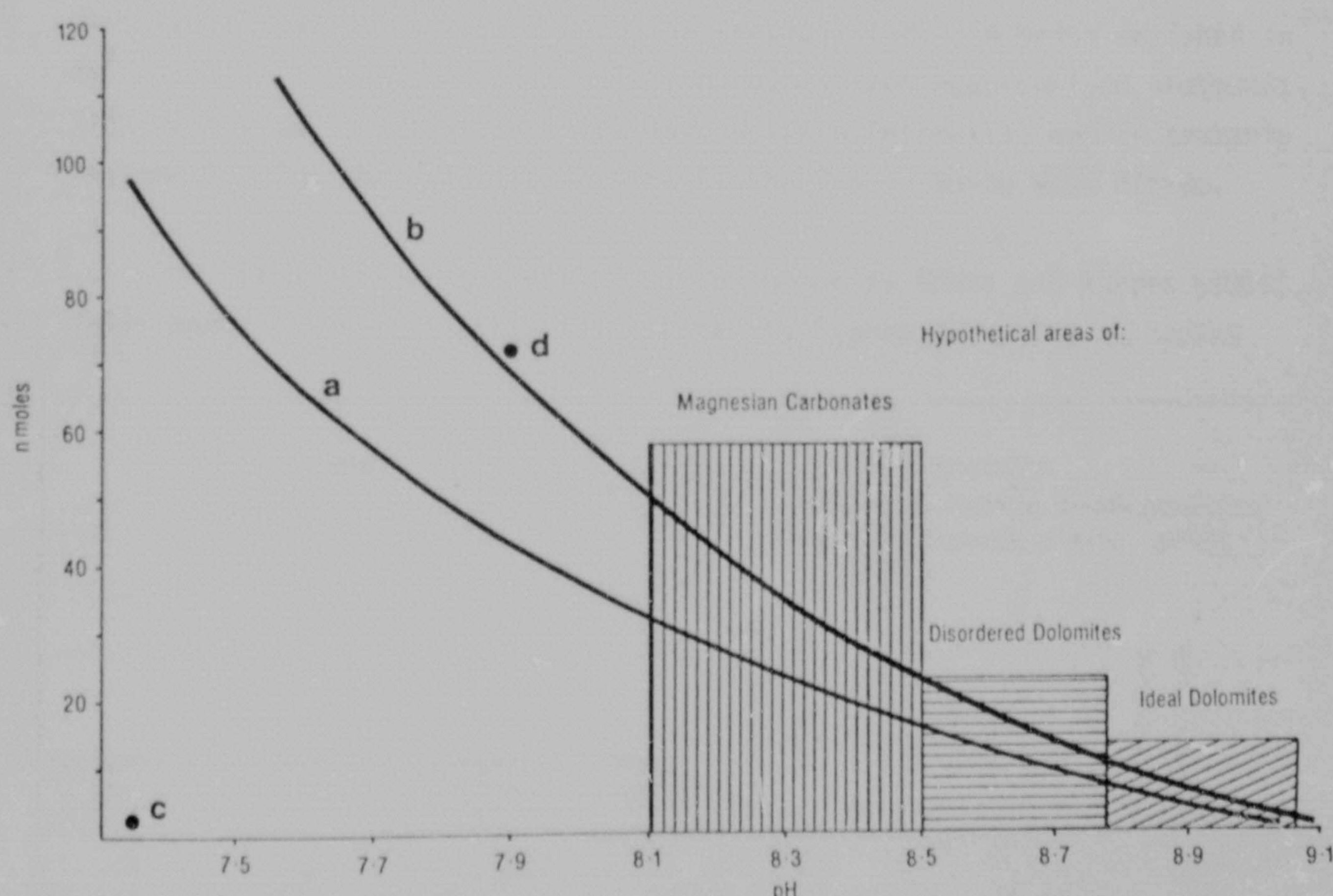


Figure 42 : Hypothetical solubility curves of $CaCO_3$(a) and $MgCO_3$(b) in water of 4-6 times normal salinity at 25°C, as functions of pH. Points (c) and (d) are calculated solubilities of $CaCO_3$ and $MgCO_3$ (after Liebermann, 1967).

illustrates the solubilities of $CaCO_3$ and $MgCO_3$, and the solid phases associated with them, under various pH conditions. As the physico-chemical parameters required to generate primary dolomite are so specific, it seems unlikely that the Malmani dolomite was formed in this manner.

3. Diagenetic dolomite

In order to dolomitize a pre-existing calcium carbonate rock it is necessary to increase the Mg^{2+}/Ca^{2+} ratio to up to 15-30, as opposed to the normal value of 5 in sea water, and this may take place during evaporative concentration. It is also important to pass large quantities of sea water through the sediment, so that sufficient Mg^{2+} ions may reach reaction sites. With these important conditions in mind, Fuchtbaüer (1974) outlined three dolomitization processes.

(i) In tropical and sub-tropical climates, evaporative conditions develop in shallow water and $CaSO_4$ is precipitated. A brine enriched in Mg^{2+} ions is formed, and this solution dolomitizes near-surface sediments. This mechanism is active in Shark Bay, Western Australia, and is probably responsible for the dolomites of the Etosha Pan in South West Africa.

(ii) "Seepage-reflux" was proposed by Adams and Rhodes (1960). Their model is schematically illustrated in Figure 43. The mechanism

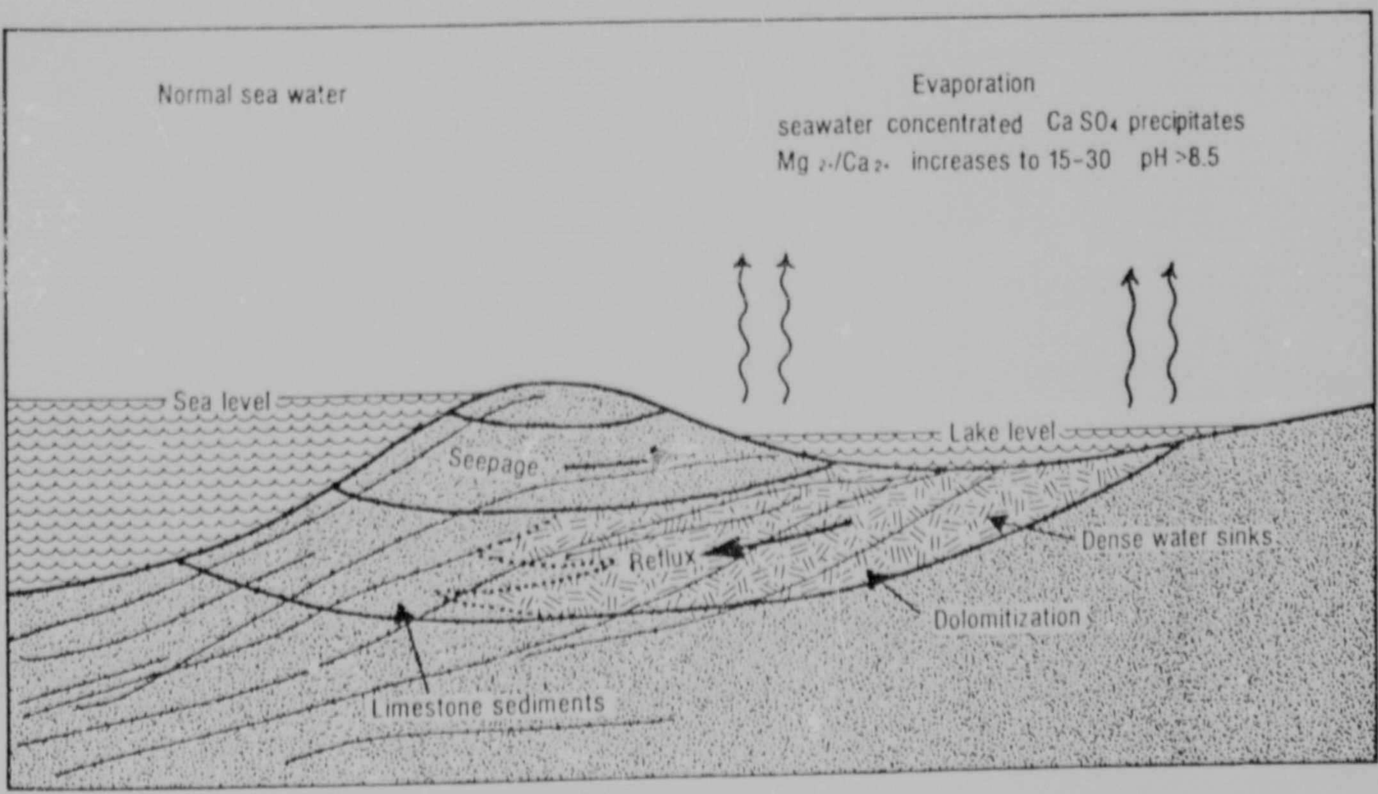


Figure 43 : Schematic arrangement of seepage-reflux as described by Adams and Rhodes (1960) adapted from Bathurst (1971).

envisages evaporative concentration in areas close to, but restricted from, an adjacent body of sea water. The water-level within the restricted area drops, as water is lost to the atmosphere, and sea water "seeps"-in to replace this loss. Heavier, more dense brines percolate downwards, and "reflux" causes dolomitization of near-surface and subsurface carbonates. This was invoked to explain dolomitization on Bonair Island, Dutch Antilles, by Deffeyes _et. al_. (1965), but subsequent borehole sampling by Lucia (1968) showed that subsurface brines did not exist. "Seepage-reflux" may occur, but this idea was modified into:-

(iii) "Evaporative pumping" which was proposed by Hsü and Siegenthaler (1969). In laboratory experiments, the migration of sea water landwards was initiated when water was evaporated from a model land-area situated adjacent to an hypothetical sea (Figure 44). Near-surface water

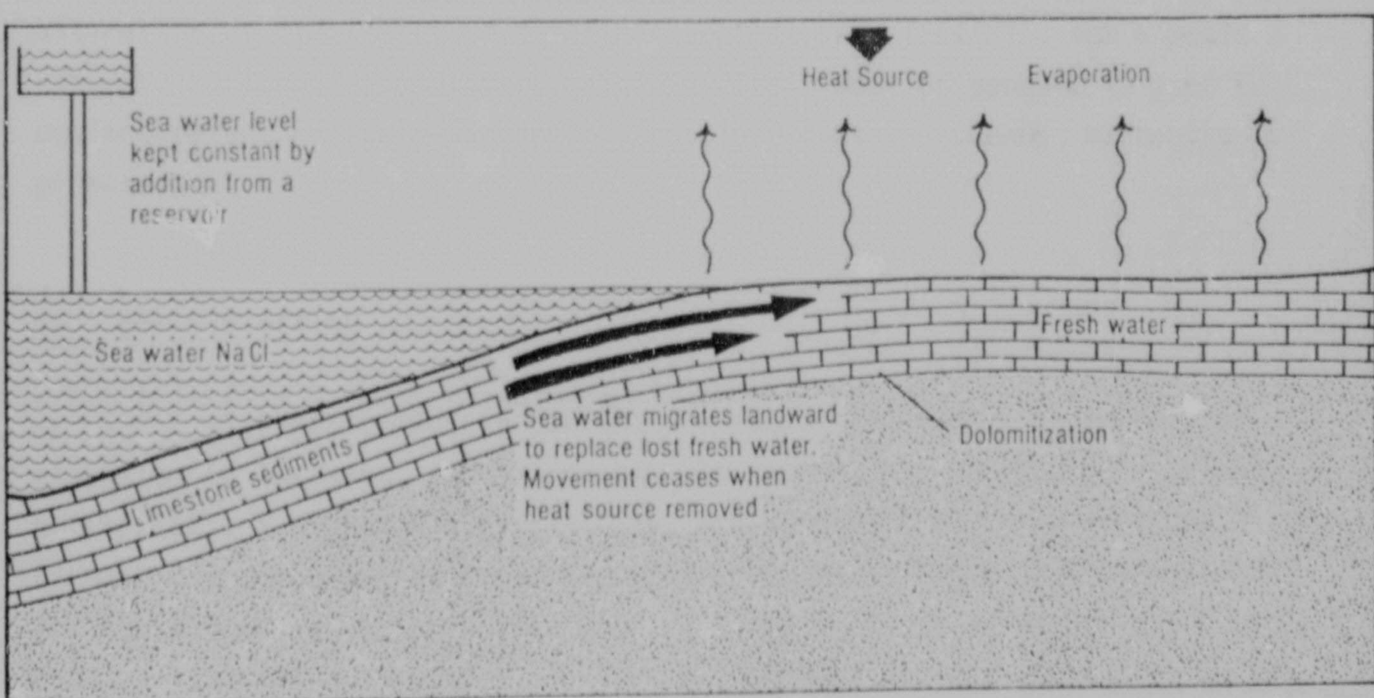


Figure 44 : Schematic illustration of the reflux model proposed by Hsu and Siegenthaler (1969).

influx was recorded and, in the Persian Gulf, dolomite is actively being formed beneath a sabkha surface, and aragonite muds are being replaced (Illing, _et. al_., 1965).

In reviewing these mechanisms and considering the previous discussion on chemical considerations, it would seem reasonable to conclude that evaporative conditions are of prime importance in modifying the physico-chemical nature of sea water to the point where dolomite is formed.

The Malmani Dolomite Subgroup contains abundant evidence of dolomitization, with the replacement of aragonite fabrics and sedimentary structures indicative of early diagenetic dolomite. This is further supported by the dolomite intraclasts frequently incorporated in the intraclastic dolomicrites, which were derived from adjacent dolomitized sediments. The stromotactoid fabrics infilled with dolosparite also reflect early dolomitization, since they must have been filled prior to compaction, which would otherwise have destroyed them. In many cases, late-diagenetic dolomitization is indicated by coarse recrystallization textures. However, the dark dolomites are enigmatic, because they do not seem to have resulted from diagenetic alteration of limestones, but neither does it seem feasible, for kinetic reasons, to consider a primary origin. Their mode of genesis is open to conjecture but an early-diagenetic, possibly contemporaneous, mechanism is proposed.

4. Silicification

Silicification in carbonate rocks has received a good deal of attention in the past, and silica has been variously regarded as a primary precipitate, a diagenetic precipitate, and as a replacement phenomenon. It has been demonstrated experimentally (Krauskopf, 1956) that between 100 and 400 ppm of amorphous silica will dissolve in fresh or marine water at 25°C. It forms monomeric silicic acid (H_4SiO_4), and the concentration is dependent upon temperature, as illustrated in Figure 45. The silicic acid is a true solution, and, when the saturation point is reached, an equilibrium is established between colloidal, or gel-like, silica and silica in solution:

$$2H_2O_{(1)} + SiO_{2(s)} = H_4SiO_{4(solution)} \qquad [5]$$

It is considered by Dapples (1959) that most of the evidence which has accumulated points to the development of chert in sediments during diagenesis, and the fact that much silica has precipitated directly from sea water. In the

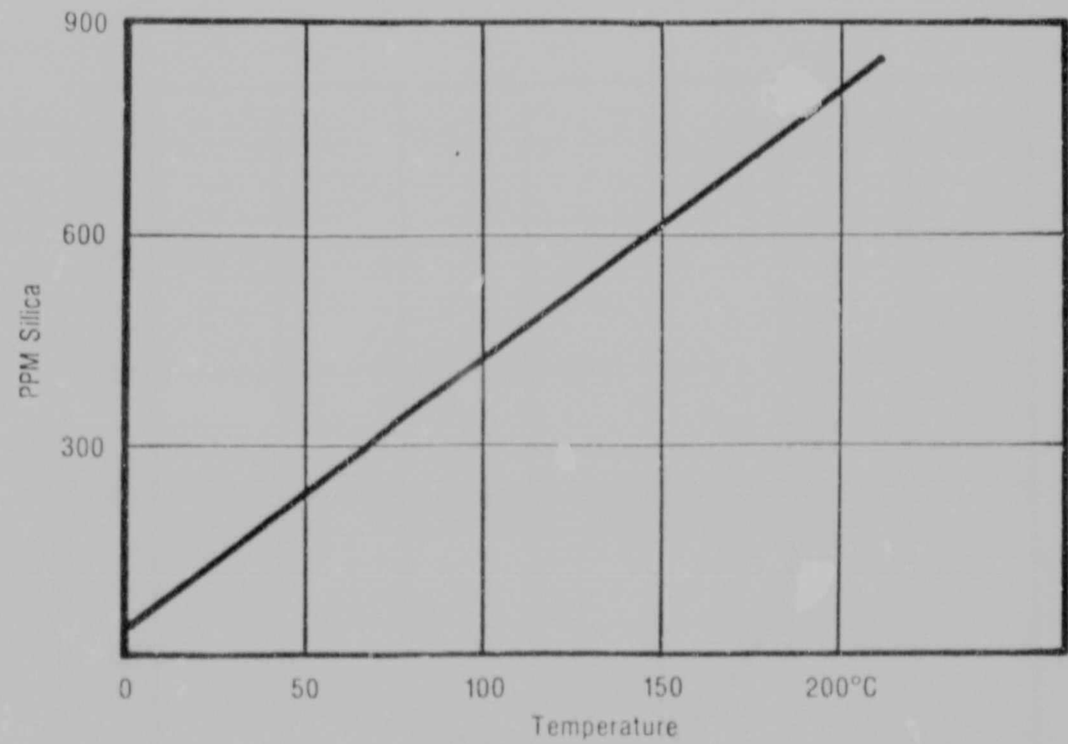


Figure 45 : Solubility of amorphous silica (after Krauskopf, 1959).

early stages of diagenesis, temperatures are rarely greater than 100°C and physico-chemical conditions are directly influenced by pH. Silica solubility is also related to pH (Figure 46) and, at pH values greater than 9, solubility rises rapidly. As dolomite is precipitated at an optimum pH of 9, under fluctuating pH conditions, each mineral should precipitate alternately. According to West (1964), silicification only affects the early dehydration stages of his well-documented diagenetic evolution sequence. This is further supported by the work of Milliker (1979) who showed that silicification of sulphate evaporites is related to mobile interstitial solutions, which precipitate silica at less than 40°C and at an early stage in diagenesis.

In the Malmani dolomite, penecontemporaneous dolomitization and silicification processes might account for the perfectly-preserved nature of many sedimentary structures and for the fact that there are no significant compaction effects. Once generated, the dolomitizing and silicifying fluids could remain active and cause coarse crystallization, as in the Complex Dolomite Zone. However, it is evident that the processes operating in the Complex Dolomite Zone were different to those affecting other parts of the stratigraphy, possibly because refluxing of fluids was increased as a result of greater evaporation rates. It is important to note that the silicification of evaporites is a diagenetic feature, and that sulphate, and possibly chloride

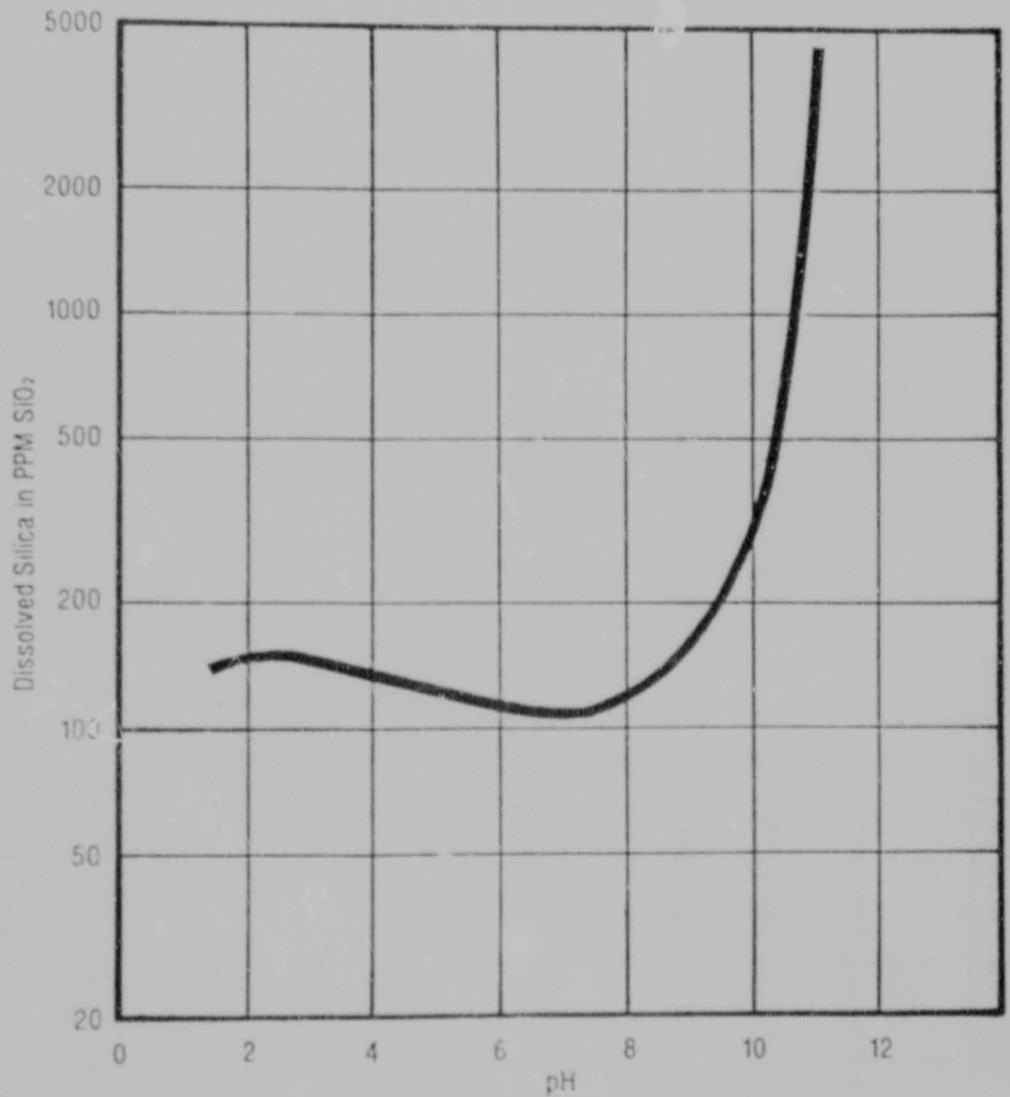


Figure 46 : Variation in SiO_2 solubility with pH. Temperature x 25°C (after Krauskopf, 1959).

ions, would enter solution at an early stage. This is significant when considering mechanisms for the transport of metal ions and subsequent mineralization. The mottled dolomite zones are indicative of replaced evaporites, and, as these only occur in certain parts of the stratigraphy, this will necessarily influence the nature of pore fluids on a local scale, and impart a stratigraphic control to mineralization.

Finally, it is concluded that several stages of dolomitization and silicification have affected the Malmani dolomite. The primary carbonate sediments were probably deposited as $CaCO_3$ in the form of aragonite, with some primary dolomite developed in places, and contemporaneous alteration and replacement gave rise to dolomicrite, dolosparite, and chert fabrics.

TABLE 5

THE STRUCTURAL ELEMENTS OPERATIVE DURING THE SEDIMENTATION OF THE MALMANI DOLOMITE SUBGROUP, IN THE CARLETONVILLE AREA

	WEST Elandsrand Property	EAST Western Deep Levels Property
Fountains Formation	South-plunging Synform	North-trending synform
Intimately-Mixed Dolomite-and-Chert Zone	North-trending Synform	North-trending north-plunging Antiform
Upper Laminated Dolomite-and-Chert Zone	Oval-shaped depression	?
Upper Dark Dolomite Zone	North-trending, north plunging Antiform	North-trending Synform
Lower Laminated Dolomite-and-Chert Zone	Dome feature ?	?
Complex Dolomite Zone	East-West trending Synform	
Lower Dark Dolomite Zone	North-trending, north plunging Antiform	North-trending, south-plunging Synform
Transition Zone	North-trending, south plunging Synform	North-stiking Antiform
Base of the Malmani Dolomite Subgroup	North-trending Antiform	North-trending Synform

Where evaporation rates were high, sub-surface dolomitizing and silicifying fluids were formed, and coarse-grained dolomite textures were generated. If these solutions remained active, recrystallization gave rise to extremely coarse-grained dolomite. Under fluctuating pH conditions the recrystallization textures would reflect different episodes of growth and dissolution, which accounts for the often close relationship between dolomite crystals and silica.

N. SUMMARY OF THE DEPOSITIONAL HISTORY OF THE MALMANI DOLOMITE SUBGROUP

1. Tetonic history

Using various forms of stratigraphic maps and panel-diagrams, the principal tectonic elements which operated during the sedimentation of the Malmani dolomite, in the study-area, have been delineated, and are presented in Table 5. This has revealed the presence of two structural features which have functioned as both positives and negatives, or, as they are described in this dissertation, antiforms and synforms. The first is a north-trending structure in the east, on the Western Deep Levels Gold Mine property, and, secondly, a north-trending structure in the west, on the Elandsrand Gold Mine property. The manifestation of these structures was not consistent, and they formed antiforms and synforms at various stages during sedimentation, which reflects a pulsating tectonic mechanism. The stratigraphic analysis has revealed the structural growth during Malmani dolomite times, and this is the result of contemporaneous tectonism.

Although the dolomites were deposited during a period of tectonic quiescence, minor structures did operate in the study-area, giving rise to local thickness variations. On a large-scale, the cyclical nature of the transition from the shallow-water Lower Laminated Dolomite-and-Chert Zone, through the deeper-water Upper Dark Dolomite Zone, and back into the shallow-water Upper Laminated Dolomite-and-Chert Zone, was possibly controlled by gentle, crustal flexing. The two persistent north-trending features are similar in orientation to the fold trends recognised in the structure contour map of the top of the Ventersdorp Supergroup, which forms the floor of the Malmani carbonate shelf. This suggests that the tectonic elements active during Transvaal sedimentation were initially generated in pre-Transvaal times. This was also concluded by Eriksson (1971) and Pretorius (1979).

Small tectonic movements, in a shallow-marine environment, could create restrictions which, under evaporative conditions, would permit dolomitizing and silicifying fluids to develop. This mechanism may have been responsible for the formation of the coarse-grained dolomite within the Complex Dolomite Zone. In this zone an east-west-trending synform was noted, which broadly parallels the Carletonville Anticline to the north, and this was probably a closely-related, sympathetic, syn-depositional, upwarp structure. It is considered that tectonic elements did affect sedimentation of the Malmani dolomite, as shown by the thickness variations within the stratigraphic zones. Most of the structures were formed in pre-Transvaal times and were caused by epeirogenic activity of the basement. Movement of the structures was generally only of a small-scale and pulsatory, during the deposition of the carbonates.

2. Summary of the palaeoenvironment

It has been postulated that the Malmani dolomite was deposited within an epeiric sea which was broadly U-shaped and open to the south-west. The extent of the Malmani shelf carbonates is illustrated in Figure 5, and it is similar in both shape and size to the present-day Persian Gulf In the northern Cape, the base of the dolomites consists of many prograding transgressive cycles. These fining-upward cycles, which grade from quartz arenites into carbonates, represent on-lap deposits which gradually migrated north-eastwards over the Kaapvaal craton. These sediments mark the transition from siliciclastic to carbonate sedimentation and the stabilization of the marine shelf.

Modern carbonates are forming in regions of continental stability, in warm, clear, shallow-marine conditions. In the Bahamas, active carbonate deposition began 4 000 years ago on a large, shallow, submerged platform. Since that time, approximately 3,5 metres of unconsolidated sediment have accumulated (Bathurst, 1971), at a rate of almost one millimetre per year. If similar rates are invoked during the formation of the Malmani dolomite, then in the Carletonville area, where 1 500 metres of carbonate are present, sedimentation took place over a period of at least 1,5 m.y. and was accompanied by subsidence averaging one millimetre per annum.

Micro-organisms in the Malmani carbonates are similar, morphologically, to those of the present time (MacGregor, *et. al*. 1974). Modern algae and stromatolites are restricted to specific environments because there are abundant predators, but, during Transvaal times, predators were non-existent and algae ubiquitous. For this reason, algae must have played a significant role in the formation of the carbonates, changing pH and CO_2 partial pressures and altering the carbonate chemical equilibrium. It is known that algae can bind Mg^{2+} and Ca^{2+} ions, which are subsequently released during diagenesis and bacterial degradation. This could be the reason why much of the dolomitization appears to be very early diagenetic.

In thin-section, textures have been detected which are similar to those described by Assereto and Folk (1976) and Chafetz (1979), reflecting primary aragonite fabrics, but there remains no clear indication as to the nature of the original carbonate in the Malmani dolomite. Much of the chemical and thermodynamic data concerning the dolomite question shows that it is unlikely for dolomite to precipitate directly from solution, but dolomicrite could form in this way since there is no evidence of alteration in many of the dolomicrite horizons. The dark dolomicrite horizons reflect deeper-water sedimentation, and indicate two major transgressive cycles; the first, during the formation of the Lower Dark Dolomite Zone, and the second during the deposition of the Upper Dark Dolomite Zone. These transgressions were caused by gentle subsidence of the whole carbonate platform, as suggested by their extremely extensive nature, being recognised in the eastern Transvaal (Button, 1973) and in the northern Cape (Beukes, pers. comm., 1980). There are abundant small-scale, shallowing-upward cycles in the dolomites, and these are typical of shelf-carbonate deposition, but there are no specific indications of subtidal, intertidal, or supratidal conditions. The mottled dolomite horizons represent replaced evaporites, and it should be noted that these are quite abundant in the Intimately-Mixed Dolomite-and-Chert Zone.

The Complex Dolomite Zone is characterized by a wide variety of dolomite lithologies deposited in complex, fluctuating environments. Very coarsely-crystalline dolomite is only well developed in this zone, and, if this was generated by either seepage-reflux or evaporative pumping mechanisms, then some form of restriction must have formed during sedimentation. This may well have been tectonically controlled. If the breccia deposits which are occasionally encountered, represent karst features, then subaerial exposure also occurred several times during the history of the Malmani sea.

Much of the dolomitization and silicification processes are early diagenetic, and this would give rise to an initial porosity. At this time, pore-fluids would have been enriched in sulphate and other ions, scavenged during the dissolution and replacement of evaporites and carbonate. Permeability conditions permitted migration of these solutions which dolomitized the sediments through which they passed. Since the dolomites show almost no compaction effects, other than stylolitization, it is reasonable to conclude that the early porosity did not survive for any length of time. During the recrystallization processes, a large quantity of organic material was expelled from the sediments. This early liquid hydrocarbon migrated, together with the interstitial pore-solutions, and occupied porous areas, such as those developed in the very coarsely-crystalline dolomite, giving rise to the admixed textures. As the dolomites have been buried beneath a thick pile of Pretoria Group sediments, temperatures greater than 140°C would have been generated, and the palaeo-oil would now be represented by a pyrobituminous residue.

The evolution of the Malmani carbonate platform poses an interesting problem in regional tectonism, since the dolomites and chemical sediments of the Olifants River Group are positioned between two episodes of clastic deposition. There are only minor clastics in the whole of the dolomite succession, which necessitates the almost complete removal of source-areas for a considerable period of time, followed by uplift. A further requirement is that the peripheral parts of the Malmani sea became negative areas which trapped and prevented any clastic influx. This environment is analogous to the Great Bahama Bank.

As the dolomites in the study-area contain few quartz arenites, it is reasonable to conclude that the Johannesburg and Vredefort granitic domes were submerged, during carbonate sedimentation, and were relatively inactive, tectonically. However, the platform as a whole was able to move in a vertical manner in order to accommodate the great thickness of sediments deposited upon it, and to permit regional transgressive phases. At the same time, this carbonate shelf was subjected to small-scale, internal deformation effects, which gave rise to synformal and antiformal features capable of modifying local sedimentary accumulation rates.

CHAPTER III

The Geochemistry of the Malmani Dolomite Subgroup