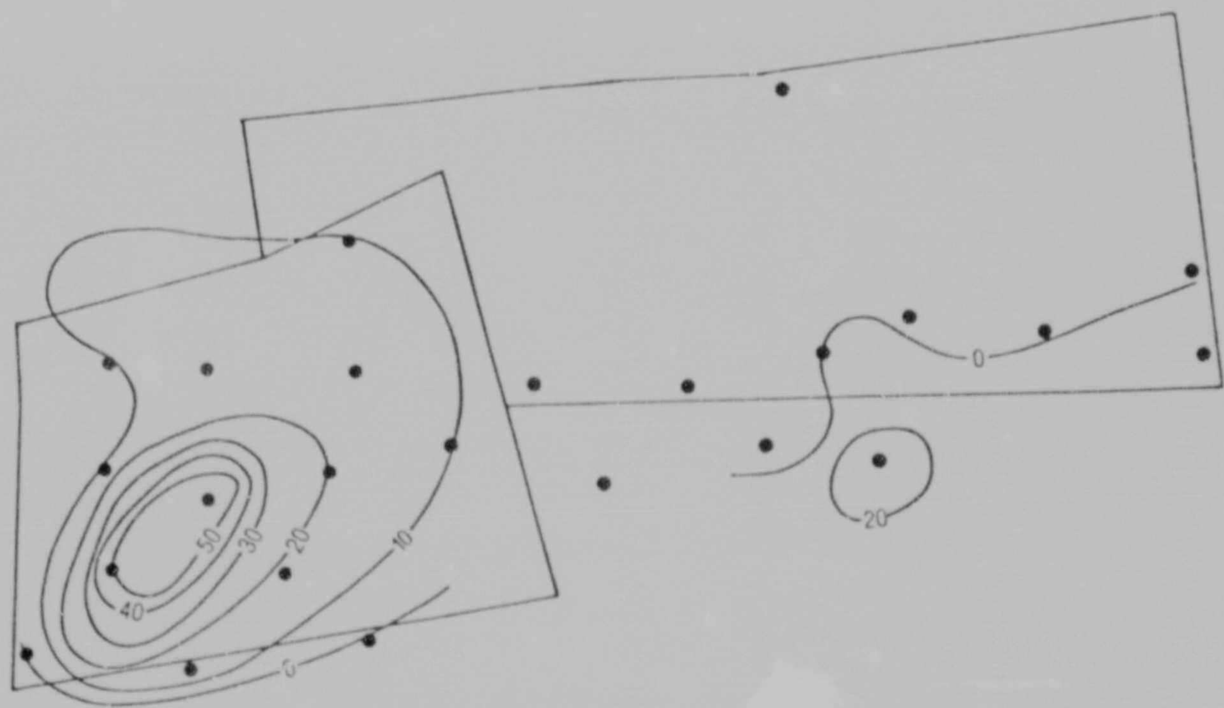



*Figure 27 : An isolith map showing the aerial variation in the total accumulated thickness of intraclastic dolomite within the Complex Dolomite Zone. Contour interval 10 metres.*

deposited and trapped during the formation of these spherical stromatolites. Some of the oncoids in the Complex Dolomite Zone resemble the pisolites of Assereto and Folk (1976), but their algal origin is demonstrated in Plate 4b, where the oncoids transform upwards into domal, laterally-linked stromatolites.

### (e) Mottled dolomite

Mottled dolomite is very distinctive and consists of white, often coarse-grained dolomite, forming either isolated or inter-connected stromotactoids, within a grey dolomicrite matrix. The stromotactoids are rarely less than 2 millimetres long, often exceeding 10 millimetres. Unlike normal stromotactoids, they form a net-like texture and may indicate relict evaporite horizons.

### (f) Dark dolomite

Dark dolomite horizons, identical in lithology to the Lower Dark Dolomite Zone, are abundant in the Complex Dolomite Zone, but do not appear to be laterally persistent. Correlation of these horizons is difficult but

PLATE 3

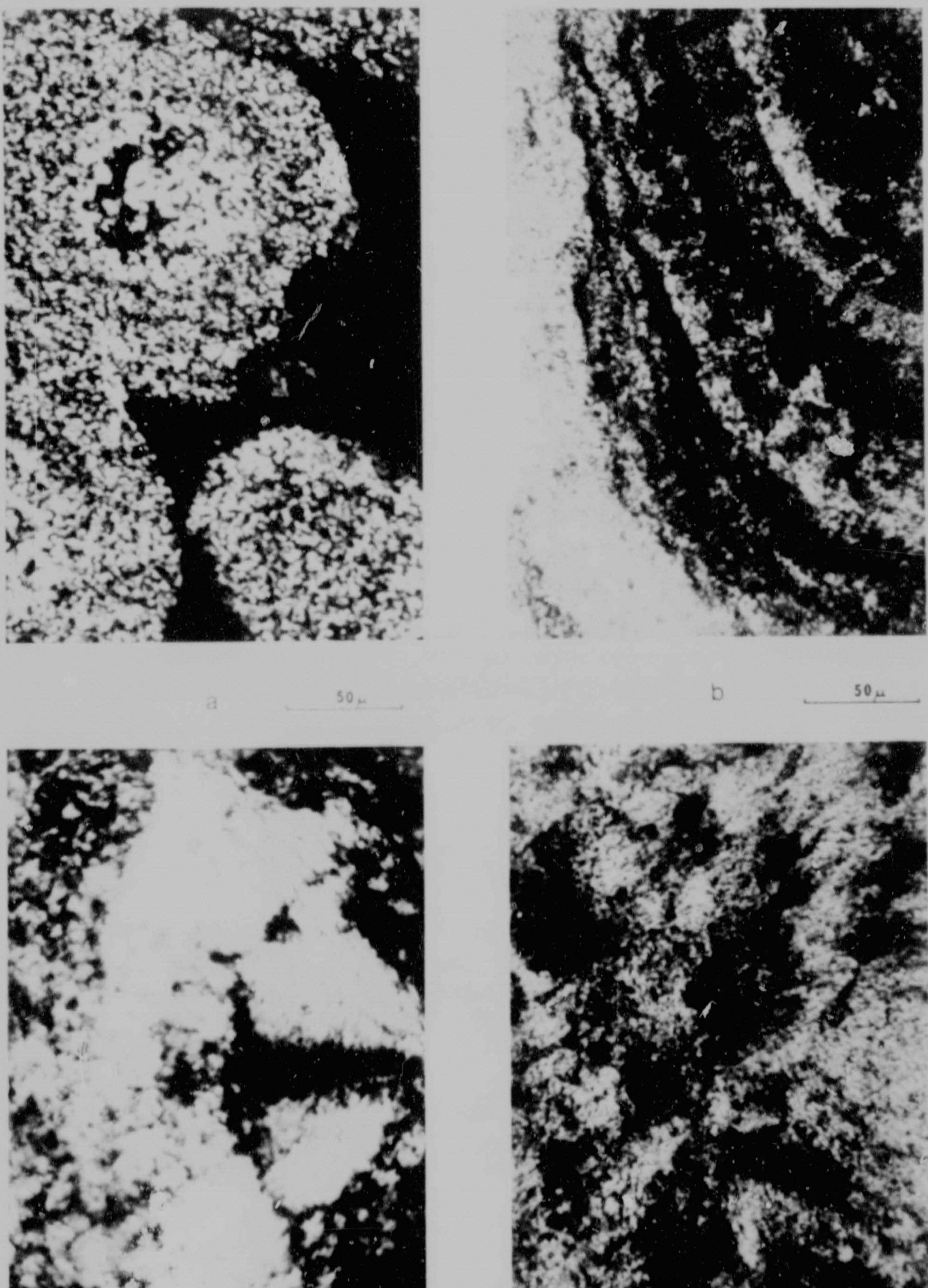
(a) Silicified ooids, with relict laminae and minor preserved dolomicrite, set in a black, carbonaceous matrix. From Slide A47. (Crossed polars).

(b) Silicified outer part of an oncoid. The dusty, black material represents the remains of the algae. The grey material is dolomicrite and the white grains are silica. The irregular nature of the laminae reflects the original algal morphology, and the length-slow, chalcedony spherulites (bottom left), former evaporites. From Slide A54.(Crossed polars).

(c) Length-slow chalcedony (centre) replacing euhedral, coarse, white dolomite rhombs, in a dolosparite matrix. Most of the dolosparite is anhedral, and carbonaceous material forms much of the matrix. From Slide A46. (Crossed polars).

(d) "Chevron-like"-dolomite, with radial extinction. The dolomite is coarse-grained and anhedral, displaying undulose and radial extinction. From Slide A80. (Crossed polars).

PLATE 3



the panel-diagram (Figure 18), shows that there is an increase in dark dolomite in the central part of the Complex Dolomite Zone. Contacts with the other dolomite types are usually sharp, but the dark dolomites are often underlain and capped by mottled dolomite, with which it displays gradational relationships. Silica is rare and columnar stromatolites are well developed. An approximate percentage of dark dolomite in the Complex Dolomite Zone was estimated, and is generally of the order of 15 per cent.

### (g) Evaporites

Length-slow chalcedony pseudomorphs after evaporites have been described by Folk and Pittman (1971), Siedlecka (1972), and many other authors. Spherulites and blades of length-slow chalcedony have been identified in several samples from this zone, and it is interesting to note the texture in Plate 3c, which consists of length-slow chalcedony replacing euhedral, coarse, dolomite rhombs in a dolosparite matrix. Positive evidence for the replacement of an evaporite mineral includes the relict fibrous habit of gypsum and tiny inclusions of sulphates. Although the former texture is common, it has not been possible to analyse the inclusions, and no sulphate was detected using the electron microprobe.

Anhydrite was identified in Borehole UD23 and consists of tiny, euhedral, twinned crystals, less than 2 microns long. The crystals are colourless, tinged pale-green in some cases, and show straight extinction. Well-formed crystals display a positive, biaxial interference figure, with a moderate-to-small 2V. Some coarse white dolomite occurs with the anhydrite, but it is difficult to determine whether the dolomite is pre- or post-anhydrite. The anhydrite occurs within stromatolite laminae (Plate 4c), and may represent primary, contemporaneous evaporitic material.

### (h) Silica

Silica is abundant throughout the Complex Dolomite Zone, but is rarely developed within dark dolomite horizons. The silica is cryptocrystalline, translucent chert, and, in core-samples, it attains a porcellaineous, white texture, due to the abrasive effects of the diamond drill, particularly when minor dolomite is present. Chalcedonic silica was detected in thin-

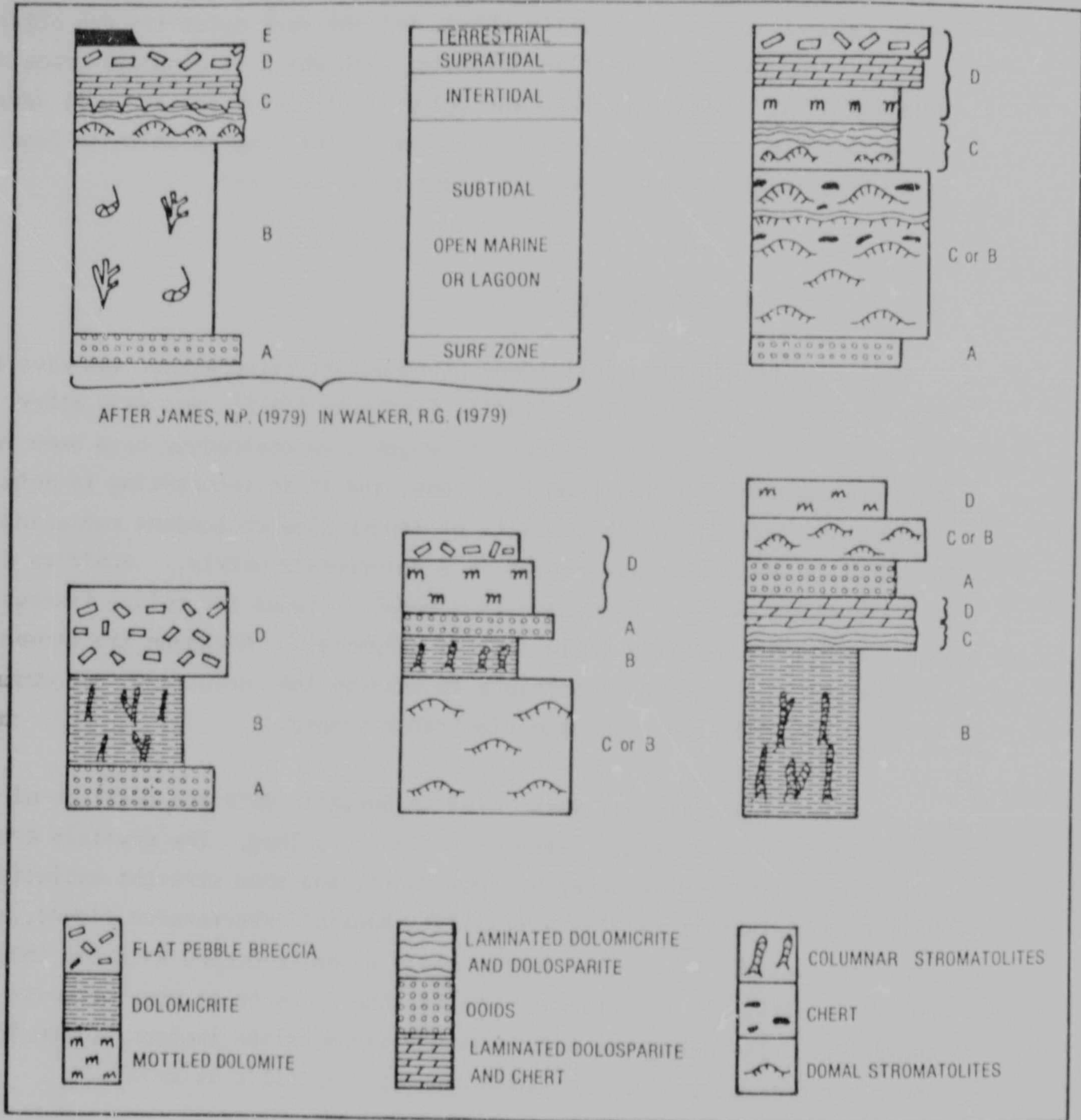



*Figure 28 : Sedimentary cycles noted within the Malmani dolomite showing fining-upward sequences.*

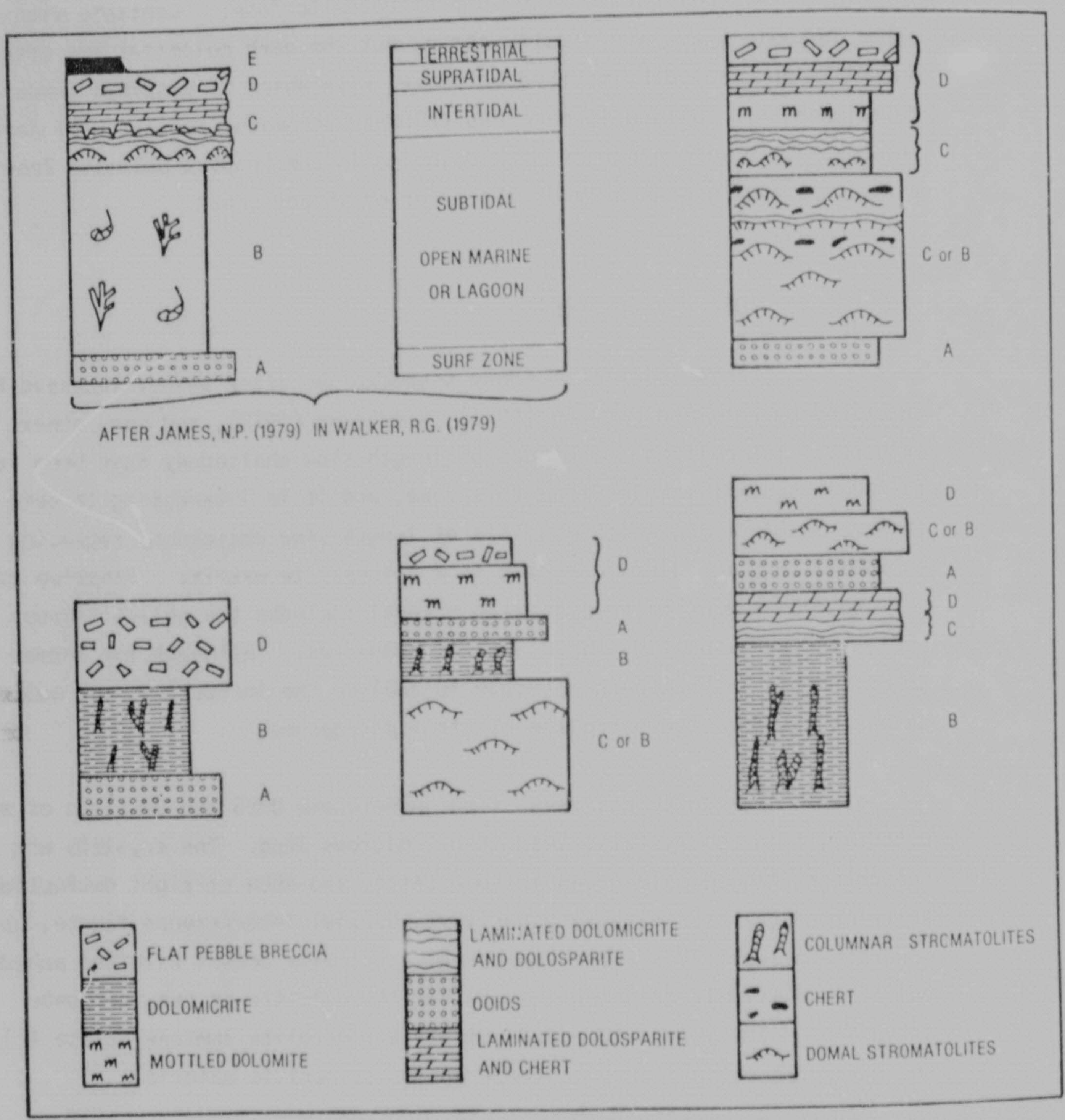



*Figure 28 : Sedimentary cycles noted within the Malmani dolomite showing fining-upward sequences.*

section, occasionally forming characteristic length-slow blades and spherulites, indicative of evaporites. The chert forms nodules and bands of varying size and thickness, and the maximum thickness of an individual layer is 1 metre. Dolomite rhombs and ooids are frequently encapsulated in the chert, some are corroded, and it is often difficult to detect them macroscopically. The rim of the stromotactoids consists of fine-grained silica, which grades into a central core of unstrained quartz. Contacts of chert with the dolomite are sharp macroscopically (Plate 4d), but in thin-section appear to be irregular.

### 3. Sedimentology

As the lower part of the Complex Dolomite Zone contains abundant ooids, sedimentation of the Complex Dolomite was initiated under predominantly shallow-marine conditions, possibly less than two metres in depth. The presence of mottled dolomite horizons, flat-pebble breccias, questionable ripple laminations, oncoids, and small domal stromatolites, tends to support this hypothesis. Above the oolitic part, the Complex Dolomite Zone is lithologically very complicated. Extremely coarsely-crystalline dolomite is abundant, together with "admixed dolomite", laminated dolomite, dark dolomicrite, and mottled dolomite horizons. Intraclastic dolomicrites and black carbonaceous mudstone units are minor components, and, in many cases, the contacts between lithologies are extremely sharp. Several shallowing-upward cycles have been noted and are illustrated in Figure 28. All the varied lithologies represent intricately-interrelated, mixed sedimentary and diagenetic environments, and, by applying Walther's Law, which states that lithologic transitions in vertical section reflect laterally migrating facies, it can be assumed that, at any one time, there existed a wide range of carbonate environments in close proximity to each other. This is precisely the sort of sedimentation taking place on the Great Bahama Bank and on the Trucial Coast (Persian Gulf). The depositional environment visualized for the Complex Dolomite Zone is illustrated in Figure 29.

The stratigraphic maps indicate that subsidence rates were greater in an east-west trending zone, located in the centre of the study-area, and this is similar to the zone of increased thickness noted in the isopach map for the Malmani dolomite (Figure 11). Eriksson (1971), outlined the presence

PLATE 4

(a) Oncoids, consisting of alternating laminae of chert and dolomicrite. These structures are identical to pisolites described by Assereto and Folk (1976), but, in thin-section, algal activity is evident. From Sample A54, Borehole UD30, depth 1 290 metres. ($^2/_3$ natural size).

(b) Oncoids, or spherical stromatolites, which consist of alternating laminae of dolosparite and chert. These oncoids are unique, as they transform upwards into laminated, domal stromatolites. From Sample A66, Borehole UD18, depth 1 652 metres. (Natural size).

(c) Anhydrite mixed with coarse, white dolomite and minor chert, within a laminated, small, domal stromatolite. From Sample A109, Borehole UD23, depth 1 742 metres. (Natural size).

(d) Contact between chert (black) and coarsely-crystalline dolomite. Chert occupies the core of a small, domal stromatolite and appears to corrode the surrounding dolomite. From Sample A105, Borehole UD19, depth 1 188 metres. ($^2/_3$ natural size).

(e) Laminated dolomite-and-chert, showing the crinkled laminae of a stromatolite. Typical of the laminated dolomite-and-chert zones. From Sample A64, Borehole UD18, depth 808 metres. ($^2/_3$ natural size).

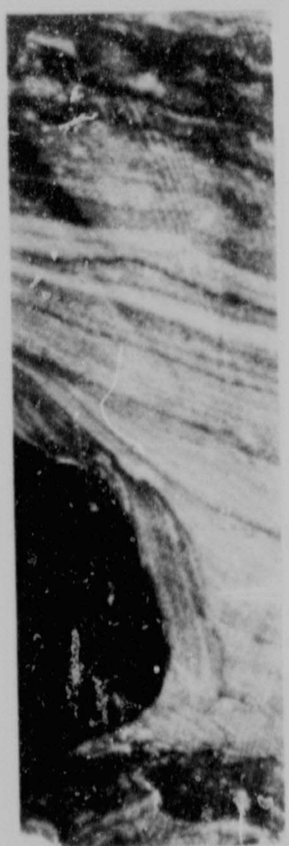
(f) Laminated dolomite-and-chert. The chert is preferentially replaced dolomicrite, leaving coarse, white dolomite layers which outline the structure of a domal, laminated stromatolite. Note the small, nodular protruberances on the laminae. From Sample A63, Borehole UD18, depth 808 metres. (Natural size).

PLATE 4

a

b

c



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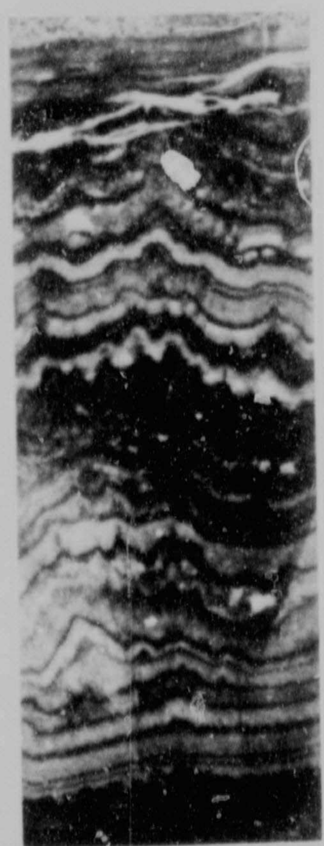

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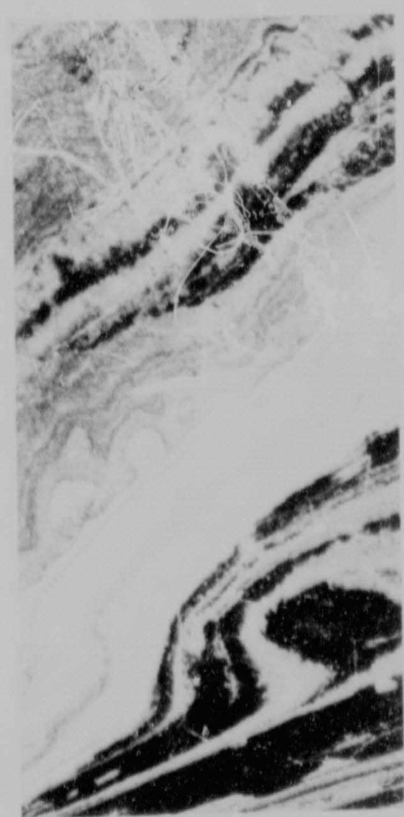

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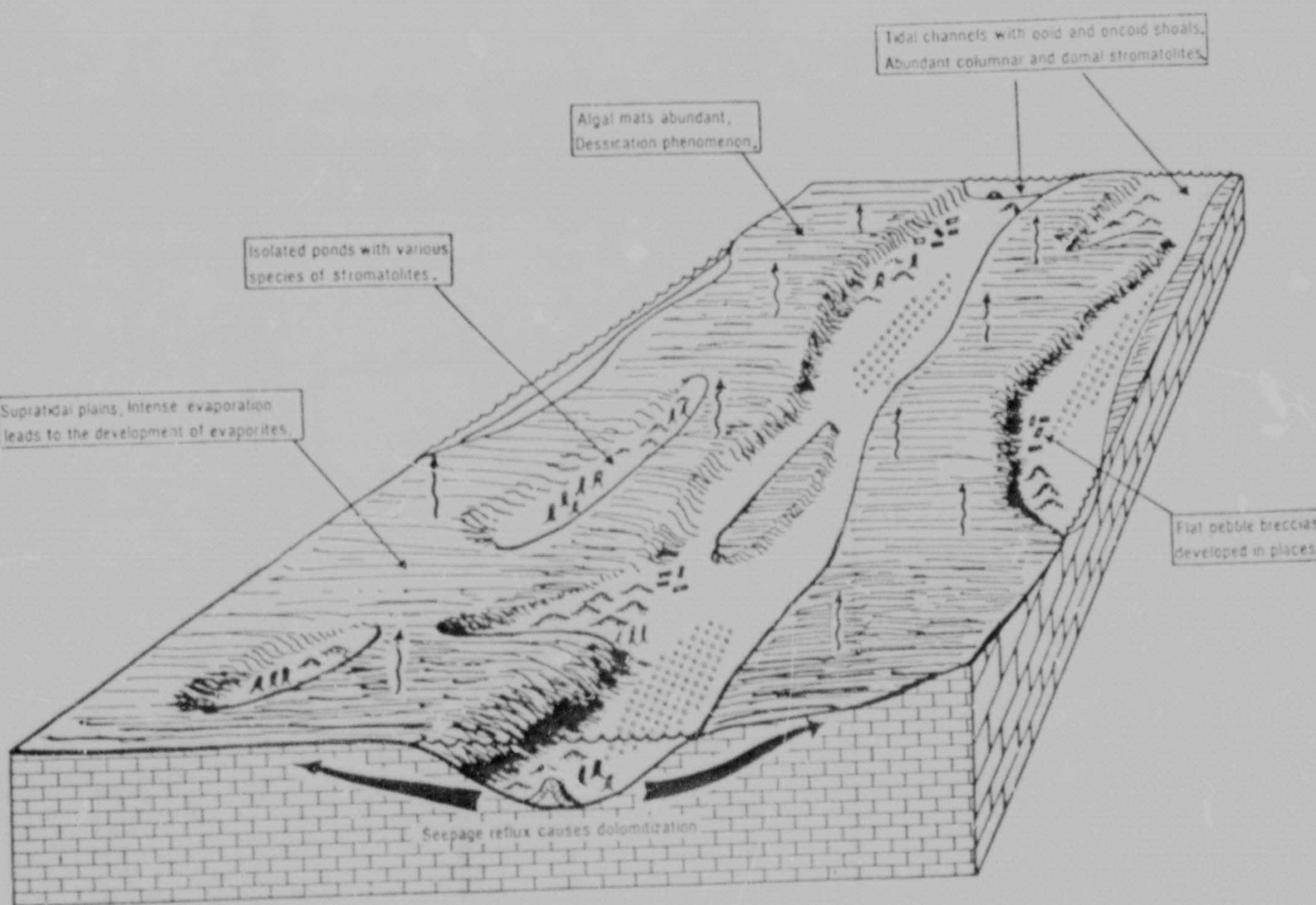


*Figure 29 : The schematic representation of the palaeoenvironment existing during the deposition of the Complex Dolomite Zone*

of the Carletonville anticline to the north of this area, and it is possible that the zone of subsidence is related to a sympathetic synclinal warp. In several boreholes there is a difference of over 100 metres in the total thickness of the Complex Dolomite Zone, when compared with surrounding boreholes, and it is considered that this is evidence of syndepositional tectonic activity.

## I. LOWER LAMINATED DOLOMITE-AND-CHERT ZONE

### 1. Introduction

This zone is very variable in thickness, within the boreholes examined, but is, on average, 77 metres thick. The base of this zone is placed at the top of the last coarsely-crystalline white dolomite horizon of the Complex Dolomite Zone, while the top is gradational over approximately

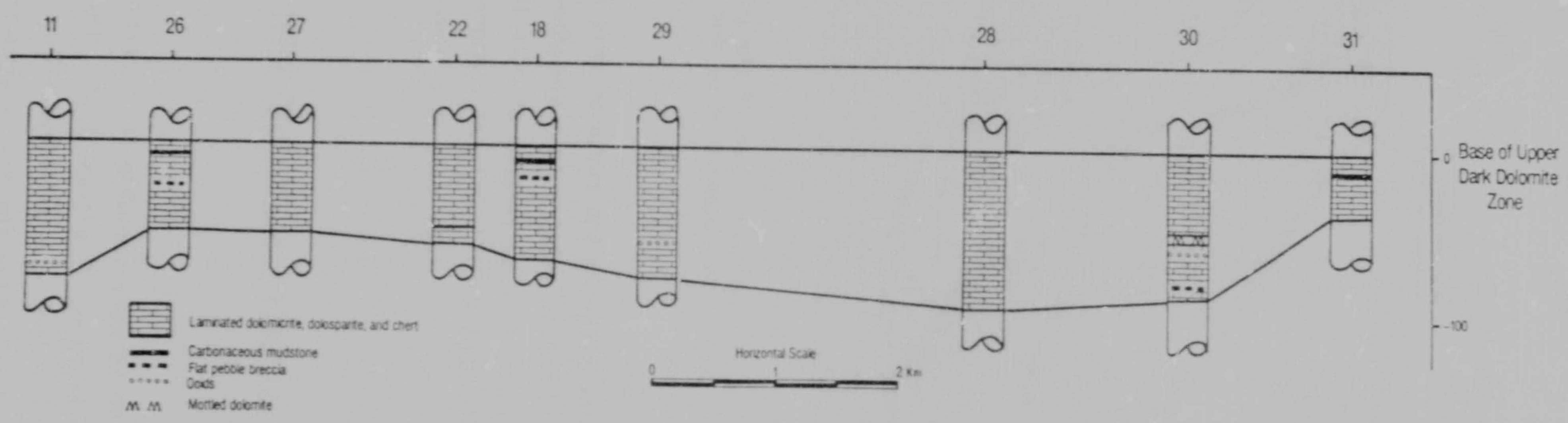


*Figure 31 : A panel-diagram illustrating the lateral variation of the Lower Laminated Dolomite-and-Chert Zone.*

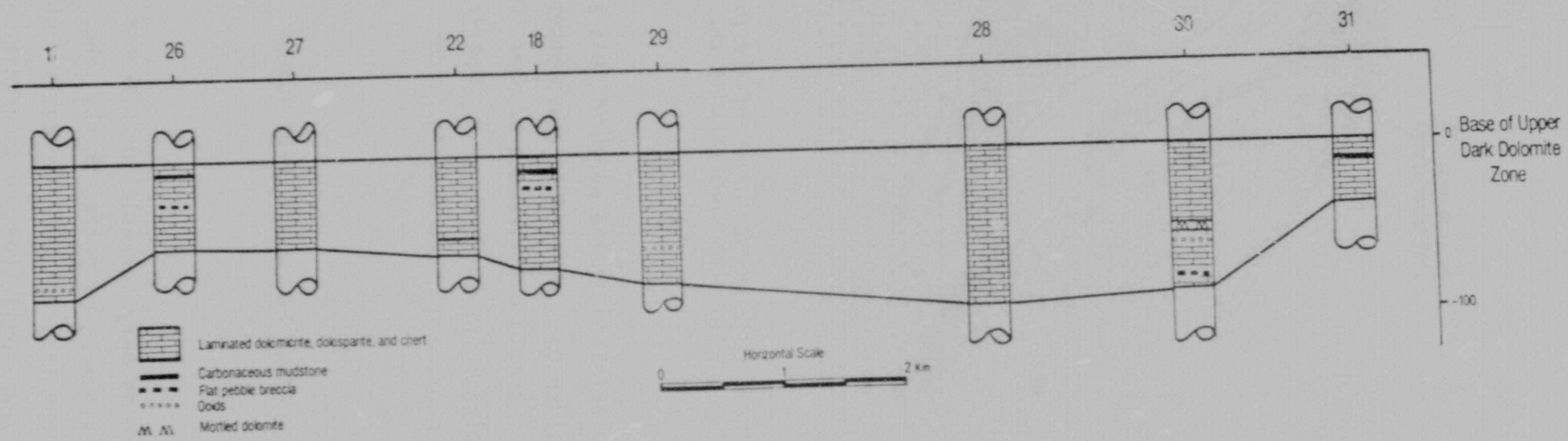


*Figure 31 : A panel-diagram illustrating the lateral variation of the Lower Laminated Dolomite-and-Chert Zone.*

5 metres into the Upper Dark Dolomite Zone. The aerial distribution of the Lower Laminated Dolomite-and-Chert Zone is depicted in the isopach map (Figure 30). This reflects thinning on an east-west trend, with a distinct

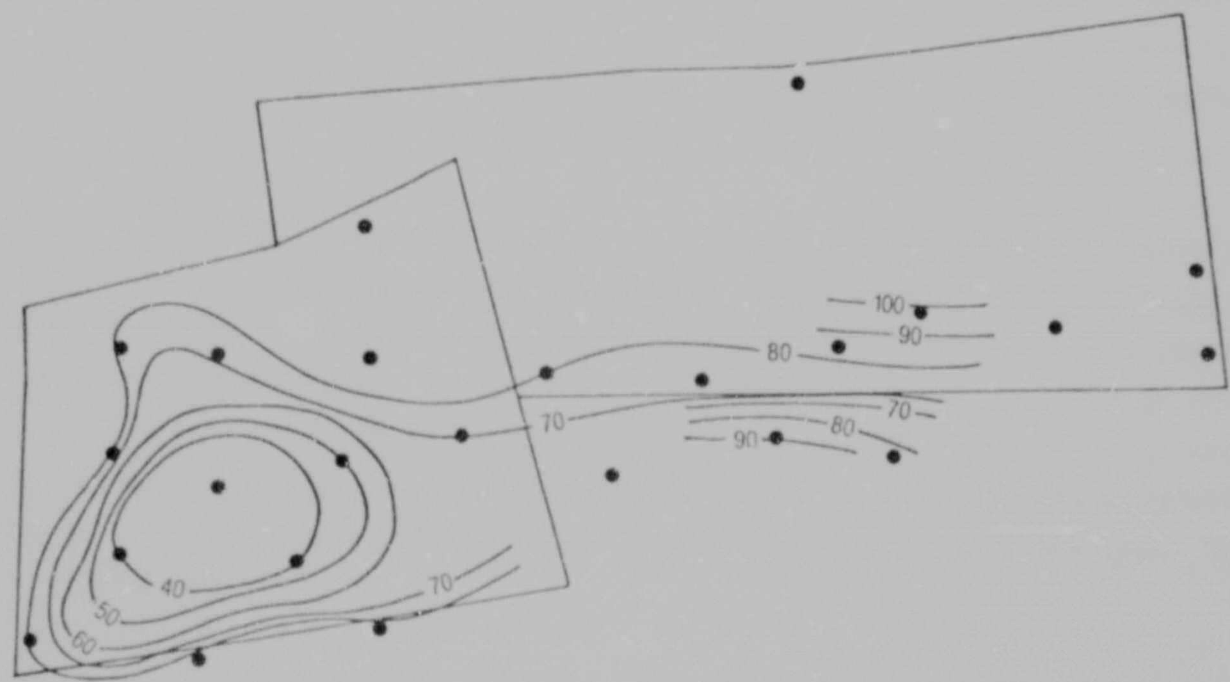


*Figure 30 : An isopach map of the Lower Laminated Dolomite-and Chert Zone. Contour intervals 10 metres.*

shallow area in the south-central part of the Elandsrand Gold Mine property. The panel-diagram (Figure 31) shows that there is a decrease in the amount of subsidence in the centre of the area, which suggests that during the deposition of this zone the central tectonic element, which had influenced the lower part of the dolomites, causing a thickening, was inactive.

Laminated dolomite-and-chert is the dominant lithology of this zone and is quite distinct. It consists of alternating, millimetre-thick, grey-and-white-dolomite laminae which rarely exceed 5 millimetres in width. They are composed of dolosparite, minor dolomicrite, and coarsely-crystalline dolomite, and the laminae are flat-lying and undulatory, often reflecting the domal outlines of stromatolites (Plate 4e). Stromotactoid fabrics are common, together with flat-pebble breccias and domal stromatolites, but ooids, oncoids, carbonaceous mudstone, and intraclastic dolomicrites are minor components. Mottled and dark-grey dolomite horizons, many of which are chert-poor, are intercalated with the laminated dolomite. Silica is present throughout this zone, is cryptocrystalline and translucent, forming

5 metres into the Upper Dark Dolomite Zone. The aerial distribution of the Lower Laminated Dolomite-and-Chert Zone is depicted in the isopach map (Figure 30). This reflects thinning on an east-west trend, with a distinct


*Figure 30 : An isopach map of the Lower Laminated Dolomite-and Chert Zone. Contour intervals 10 metres.*

shallow area in the south-central part of the Elandsrand Gold Mine property. The panel-diagram (Figure 31) shows that there is a decrease in the amount of subsidence in the centre of the area, which suggests that during the deposition of this zone the central tectonic element, which had influenced the lower part of the dolomites, causing a thickening, was inactive.

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Small brecciated layers are occasionally developed within the Lower Laminated Dolomite-and-Chert Zone. These consist of clast-supported, angular chert and dolomite fragments, cemented by silica and, less commonly, carbonaceous mudstone. In the borehole-core, it was not possible to determine the origin of the breccias, but they may be indicative of early karst formation. The Lower Laminated Dolomite-and-Chert Zone becomes progressively darker in colour and less laminated upwards and grades into the Upper Dark Dolomite Zone.

## 2. Relict aragonite fabrics

Palisade structures are present in some stromatolites of this zone, and, in thin-section, it is possible to recognise a distinctive "chevron-like" pattern in the associated dolomite (Plate 3d). This texture is produced by the undulose extinction of the component crystals and, in many respects, resembles the crossed-lamellar fabrics found in modern marine molluscan shells. These are composed of organised aggregates of micron-sized crystals, arranged in layers (Bathurst, 1971; Figures 19 and 24). The aggregates differ from species to species, in orientation and mineralogy, but are essentially composed of tiny aragonite needles. In the crossed-lamellar texture, the aragonite laths are arranged normal to the shell surface, and, in the nacreous texture, they lie parallel to the surface, giving rise to a brick-like fabric, similar to that shown in Plate 5a. This also resembles the fabrics described by Assereto and Folk (1976), which are attributed to the recrystallization of aragonite in pisolites. It is considered that these "chevron-" and "brick-like" textures, found within the Lower Laminated Dolomite-and-Chert Zone, and detected within other parts of the dolomites, are indicative of replaced, primary aragonite. As these fabrics are frequently associated with stromatolites, they may reflect the influence of algal organisms, as suggested for the precipitation of aragonite in ooids.

3. Sedimentology

With the presence of abundant fenestrae, ooids, flat-pebble breccias, and small domal stromatolites, the overall signature of the Lower Laminated Dolomite-and-Chert Zone is of a shallow-marine environment. Laminated dolomites with fenestral fabrics have been described from many supratidal areas, particularly fine examples have been recorded by Shinn, *et. al*. (1965) from the Bahamas, and a shallow-water origin is proposed for these zones. The isopach data displays a distinct oval-shaped area of thinning in the west, on the Elandsrand Gold Mine property, and an east-west zone of thinning. The latter is the reverse of the trend depicted in the previous zones, but the former is similar to pre-existing trends. This suggests the activity of undulatory, pulsating tectonics.

## J. UPPER DARK DOLOMITE ZONE

1. Introduction

The Upper Dark Dolomite Zone is very uniform in thickness and is readily identified in the boreholes. It attains a mean thickness of approximately 136 metres with a standard deviation of 15,41. The structure contour map (Figure 32) of the base of this zone, suggests the presence of

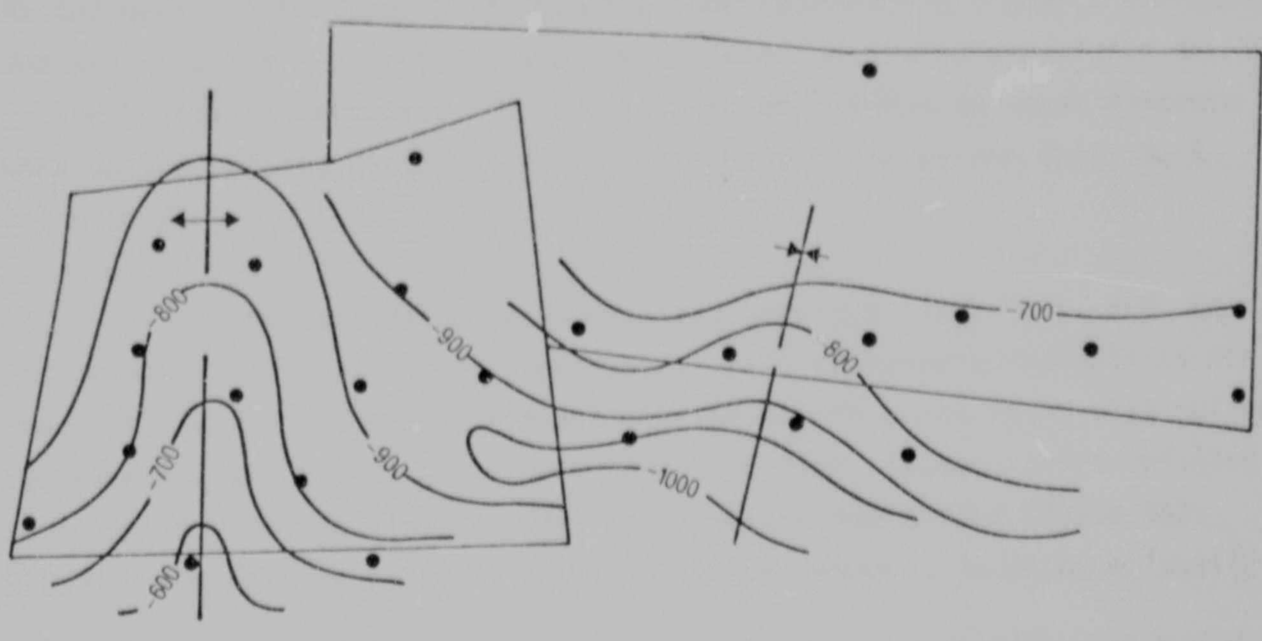


*Figure 32 : A structure contour map of the base of the Upper Dark Dolomite Zone. Contour interval is 100 metres, and all depths have been taken from a datum of 1 828,74 metres above sea level.*

two north-trending structures, which are similar to those shown in the Fountains Formation, and the base of the dolomites. In Figure 33, a

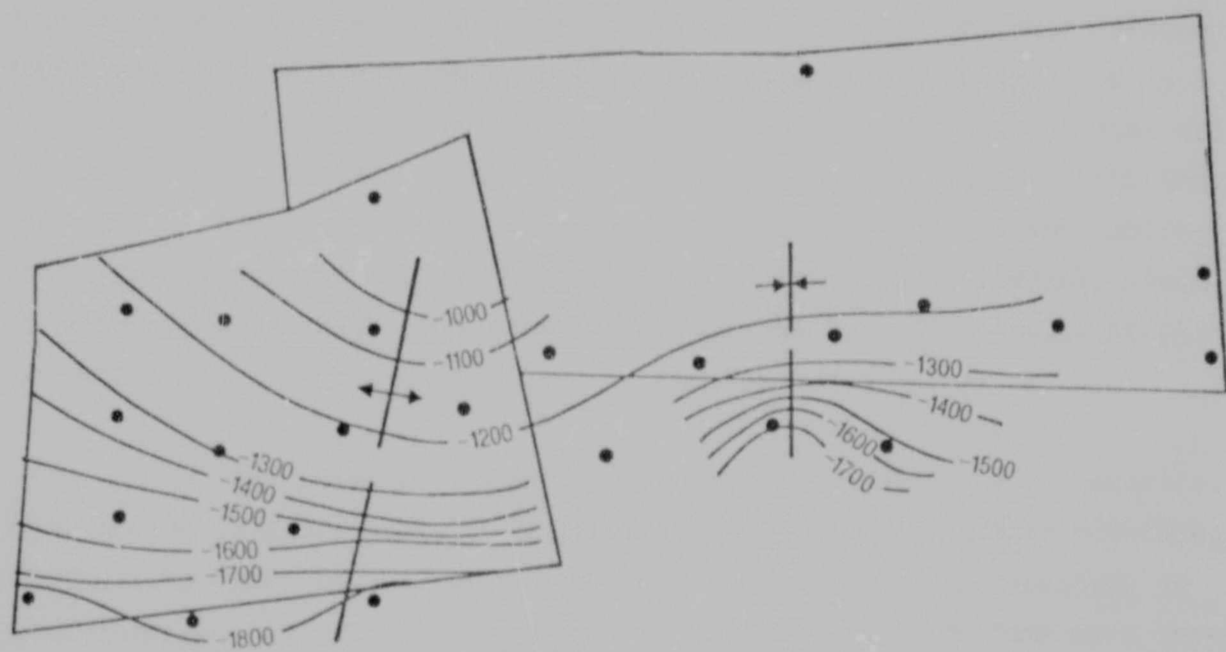


*Figure 33 : A structure contour map of the top of the Ventersdorp lavas using the base of the Upper Dark Dolomite Zone as a datum. Contour interval 100 metres.*

structure contour map has been compiled of the top of the Ventersdorp Supergroup, using the base of the Upper Dark Dolomite Zone as a datum line. This map reveals the topography of the pre-Malmani basement existing during the sedimentation of this zone, and shows the presence of a north-plunging antiform in the west, and, a north-south trending synform in the east. As the base of the Upper Dark Dolomite Zone represented a planar sedimentary feature, and these structures are almost coincident with structures developed in the Fountains Formation, it is concluded that these tectonic elements were active before, during, and after the deposition of the Upper Dark Dolomite Zone.

The dark dolomite is massive, dark-grey in colour, and, apart from minor exceptions, it is chert-poor. Tall columnar stromatolites are abundant, set in a fine-grained dolomicrite matrix which has a distinctive, speckled texture. This texture is formed by flat stromotactoids infilled with coarsely crystalline dolomite and fine-grained silica (Plate 5b). Although the dark dolomite is essentially homogeneous, it is occasionally laminated and mottled, with minor intraclastic horizons developed in places. Carbonaceous mudstones are uncommon, except in Borehole UD24, where numerous metre-thick bands are present, particularly towards the base of this zone. A pale, green-coloured mineral was observed in several of these carbonaceous mudstones, and this was subsequently identified as anhydrite. It is patchily developed, possesses a texture suggestive of flow, and does not lie parallel to bedding planes. The precise mode of origin of this anhydrite is unknown, but it is either diagenetic or hydrothermal. A four metre-thick quartz arenite occurs in Borehole UD23 and this is unusual, since no other arenites have been detected within the Malmani dolomite stratigraphy of this area, except near the base of the Fountains Formation.

The columnar stromatolites are often difficult to identify. Each column is approximately 10 millimetres in diameter and is branched, as shown in Plate 6a. From the borehole-core, it was not possible to determine the maximum vertical heights, but individual columns were traced over 20 centimetres, and true heights may be more than this. Stromotactoids are commonly developed between columns, and inter-column dolomicrite is often laminated. Domal stromatolites are present in this zone, but are not common, with the domes generally laterally-linked, and usually less than 5 centimetres high.

## 2. Sedimentology

There are many similarities between this zone and the Lower Dark Dolomite Zone, but, because there is a paucity of sedimentary structures, it is not possible to make specific deductions about the palaeoenvironment. The upper and lower contacts of this zone are extremely sharp, and this implies a dramatic change in the physico-chemical conditions. Structures indicative of shallow, high-energy environments are absent and it is considered that, as in the Lower Dark Dolomite Zone, deposition took place under quiet, possibly deep-water conditions. This reflects marine transgression. The isopach map (Figure 34) and panel-diagram (Figure 35), both illustrate the fairly uniform thickness of this zone, although some thinning is apparent in the central part of the Elandsrand Gold Mine property, which suggests the syndepositional influence of the persistent, north-trending antiform. An east-west trend is also evident on the southern boundary of

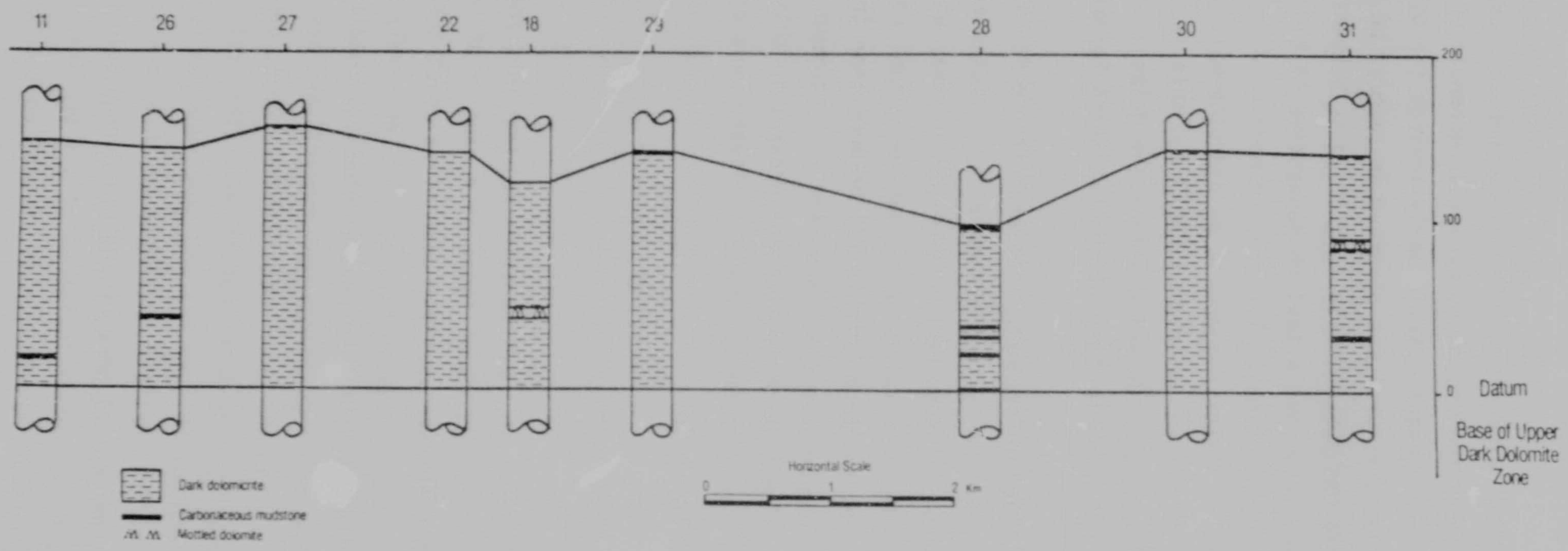


*Figure 35 : A panel-diagram illustrating the lateral variation within the Upper Dark Dolomite Zone.*

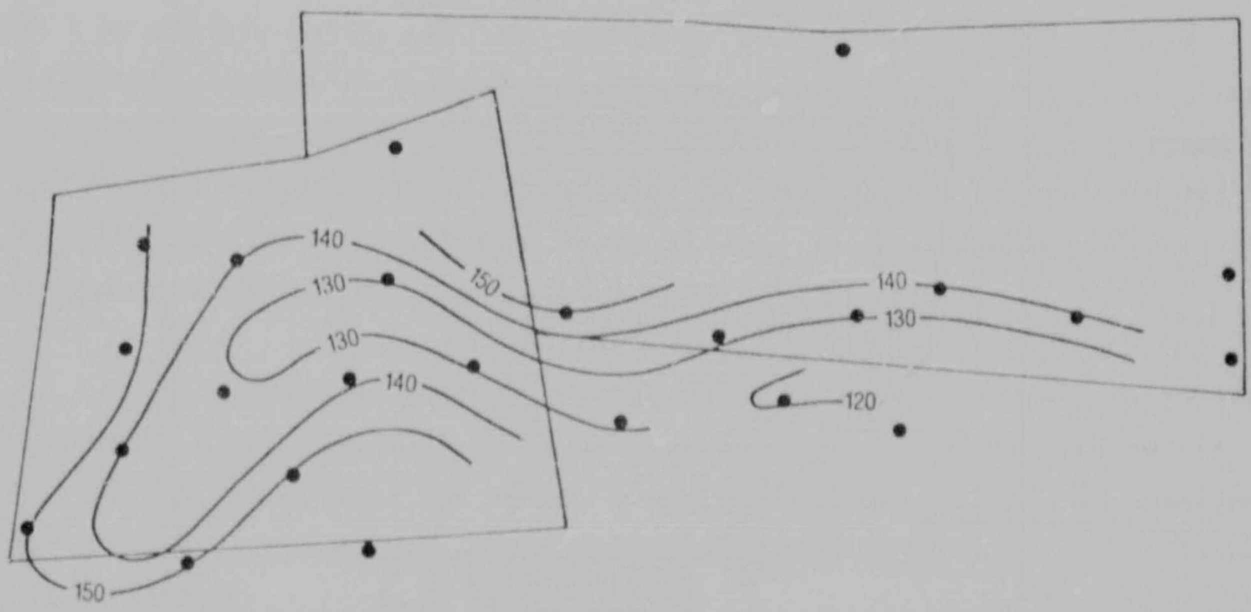


*Figure 34 : An isopach map of the Upper Dark Dolomite Zone. Contour interval 10 metres.*

the Western Deep Levels Gold Mine property, but this may result from the small number of control points in that area. It is concluded that during the sedimentation of this zone tectonic activity was at a minimum in the study-area, and this is the same as the findings of Eriksson (1971).

## K. UPPER LAMINATED DOLOMITE-AND-CHERT ZONE

### 1. Introduction

This zone is lithologically similar to the Lower Laminated Dolomite-and-Chert Zone. However, intercalated mottled and dark-grey dolomite horizons are common, and this zone is much thicker, averaging approximately 136 metres (see Table 1). In the isopach map (Figure 36), an oval-shaped area of thickening is shown which is the opposite to that found in the Lower Laminated Dolomite-and-Chert Zone. This is also the reverse of the trend shown for the Upper Dark Dolomite Zone, and is possibly the result of a pulsating tectonic action. The isopach data elsewhere in the area does not permit accurate contouring, and it is not possible to assess the nature of other structures influencing sedimentation of this zone.

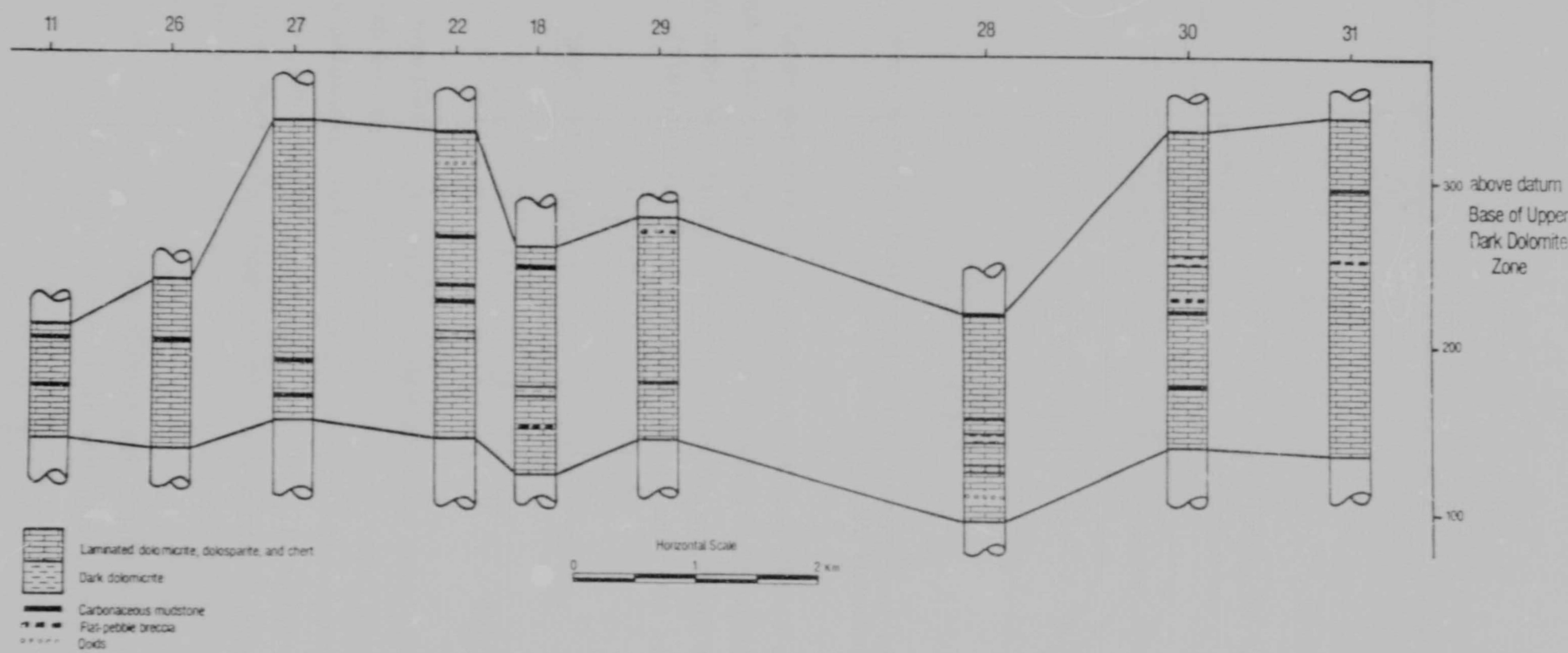


Figure 37 : A panel-diagram illustrating the lateral variation of the Upper Laminated Dolomite-and-Chert Zone.

As in the Lower Laminated Dolomite-and-Chert Zone, flat-pebble breccias, stromatactoids, and small domal stromatolites are abundant, together with occasional ooids, oncoids, and minor brecciated horizons. Chert is ubiquitous, except in some of the dark dolomite and mottled horizons, and, in many siliceous bands, length-slow chalcedony spherulites are present (Plate 5c). Stromatolites are similar to those in the Lower Laminated Dolomite-and-Chert Zone, and palisade structures are common. Most of the stromatolite domes are less than 5 centimetres in height.

Veins of white dolomite, which occupy fractures and cavities frequently associated with small brecciated bands, carry small cubes of pyrite, and, in some of the veins, a crystallization sequence is observed, with coarsely-crystalline, white dolomite precipitated first, then silica, and pyrite last.

## 2. Sedimentology

This zone was deposited in an environment which was identical to that existing during the formation of the Lower Laminated Dolomite-and-Chert Zone. However, the panel-diagram (Figure 37), and the isopach map (Figure 36) show that tectonic activity had changed. Although the palaeoenvironment was essentially dominated by shallow-water conditions, accumulation

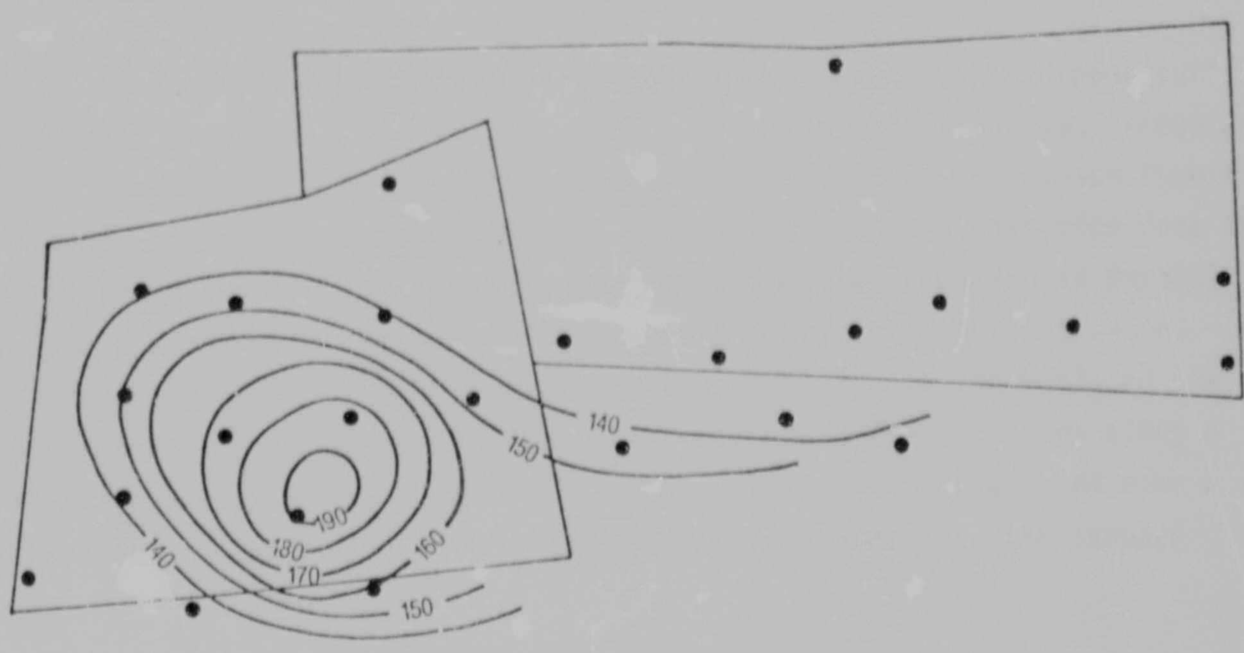


*Figure 36 An isopach map of the Upper Laminated Dolomite-and-Chert Zone. Contour interval 10 metres.*

rates were higher in the east, on the Elandsrand Gold Mine property, and, to some extent, in the vicinity of Borehole UD30. This is attributed to downwarping of the two north-trending structures, which have been prevalent in the lower zones of the Malmani dolomite. It is interesting to note, that the structure in the west appears to have changed from an antiform to a synform feature, which has resulted in a thickening of the sediments, whereas, before, most of the zones have been characterized by a thinning in this area. The contact with the overlying Intimately-Mixed Dolomite-and-Chert Zone is gradational, over a few metres, and, since the lithologies of these zones are dissimilar, the transition is readily distinguished. The overall change from the Lower Laminated Dolomite-and-Chert Zone, through the Upper Dark Dolomite Zone, and into the Upper Laminated Dolomite-and-Chert Zone, seems to represent a major sedimentary cycle. The sedimentological evidence suggests the transition from shallow, to deeper, and back into shallow-water conditions, which implies a major marine transgression and regression. The transgression was probably caused by regional shelf subsidence, whilst the regression could reflect either, progradation of sediments, or regional uplift. This episode may have been instrumental in modifying the local structures, and their influence on sedimentation.

## L. INTIMATELY-MIXED DOLOMITE-AND-CHERT ZONE

### 1. Introduction

In the Carletonville area, this zone represents the upper part of the Malmani dolomite stratigraphy, and is overlain with a marked, irregular plane of unconformity by the chert breccia deposit of the Fountains Formation. This zone attains a mean thickness of 234 metres, and the deviation from the mean is large, with a minimum thickness of 173 metres recorded in Borehole UD18 and a maximum of more than 300 metres in UD27. Two north-trending features are evident in the isopach map (Figure 38). In the west, on the Elandsrand Gold Mine property, the Intimately-Mixed Zone thickens along a north-north-westerly trend, whilst in the east it apparently thins over a north-striking, northward plunging antiformal feature. In the isopach

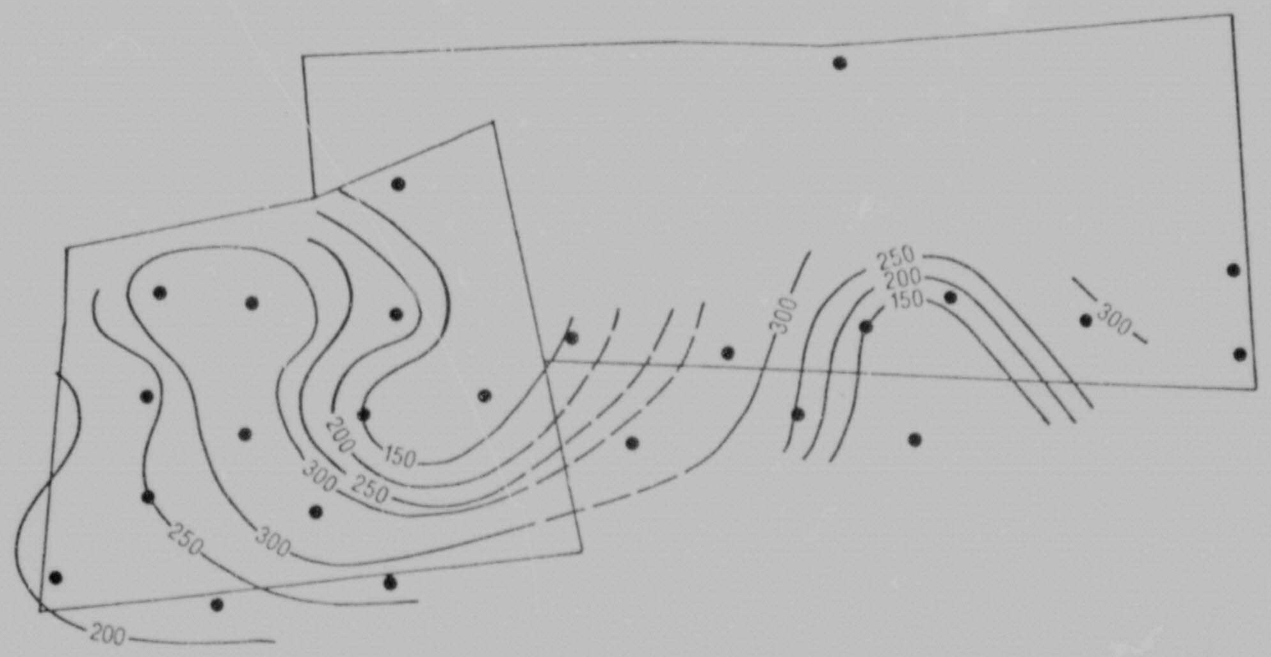


*Figure 38 : An isopach map of the Intimately-Mixed Dolomite-and-Chert Zone. Contour interval 50 metres.*

map of the Fountains Formation (Figure 39), a thickening in the west is evident which is almost coincident with the trend developed in the Intimately-Mixed Zone. This probably represents syn-depositional down-warping. The

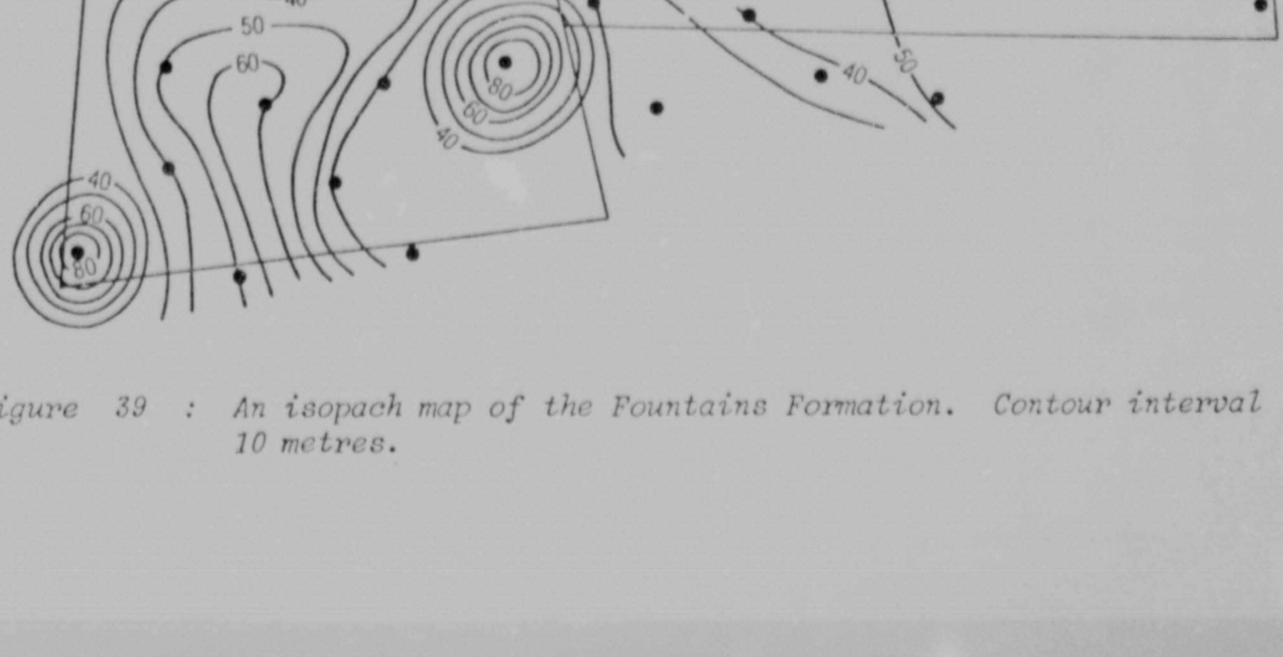


*Figure 39 : An isopach map of the Fountains Formation. Contour interval 10 metres.*