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The geology of the Malmani Dolomite Sub-Group in the Carletonville area, Transvaal

Clay, Andrew Neil

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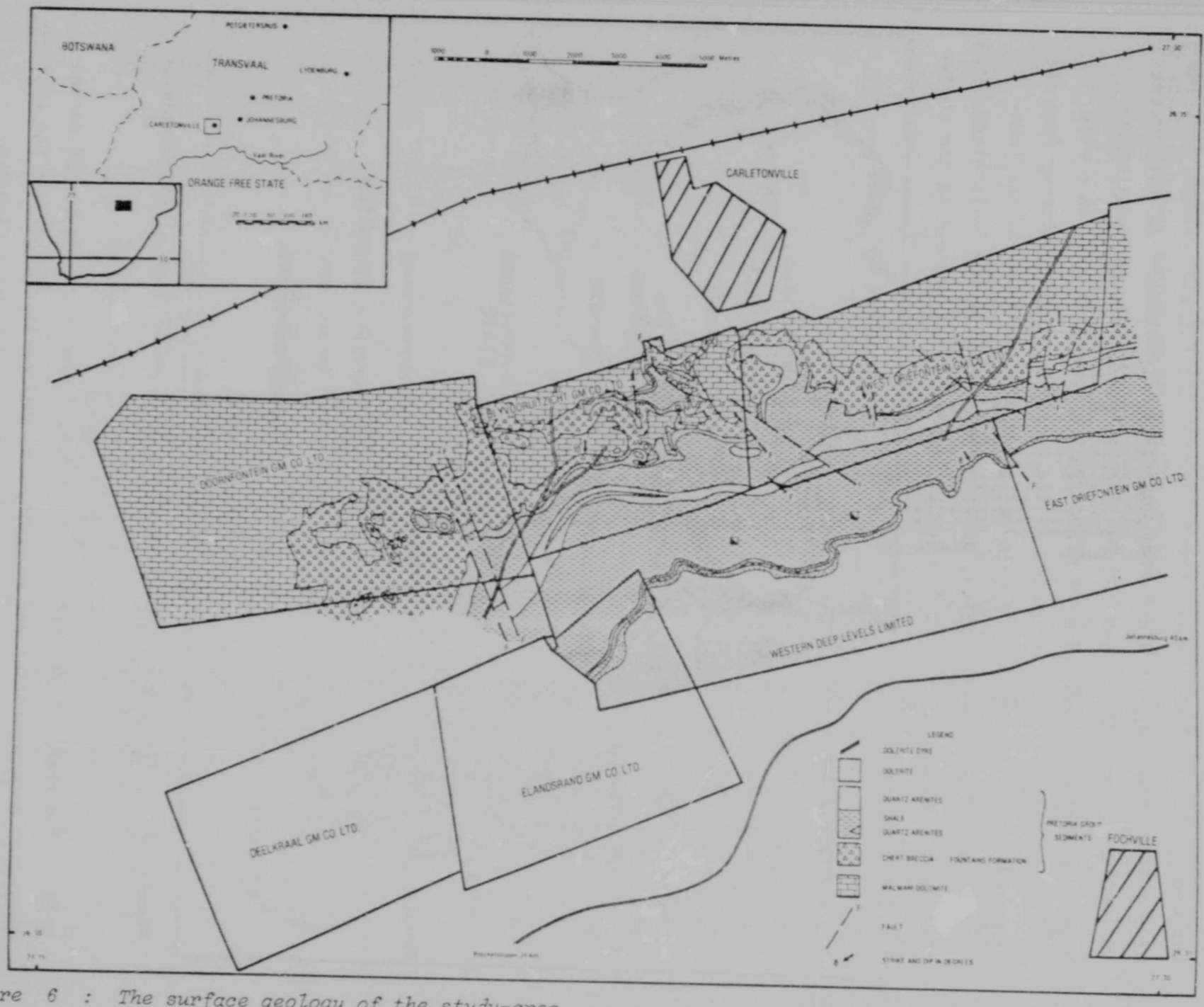


Figure 6 : The surface geology of the study-area.

At surface, the geology of the study-area consists of a sequence of east-west-striking arenaceous and argillaceous deposits of the Pretoria Group, the base of which consists of the Fountains Formation chert breccia (Figure 6). These rocks unconformably overlie the carbonates of the Malmani Dolomite Subgroup, and all the units dip at between 5 and 10 degrees to the south. Several dolerite dykes, trending predominantly north-south, are present in the area, together with occasional sills. In total, all the sedimentary rocks of the area form an accumulated thickness of approximately 10 000 metres, and represent the contents of the Rand Basin.

The Transvaal Supergroup, in the study-area, rests unconformably upon the volcanic and sedimentary rocks of the Ventersdorp Supergroup, which has been dated at between 2 643 ±80 m.y. (Van Nierkerk and Burger, 1978), and 2 245 ±90 m.y. (Burger and Coetzee, 1973). After the sedimentation of the Transvaal Supergroup, a thick sequence of acid lavas, known as the Rooiberg Felsites, were extruded, and these were considered to mark the opening phase of Bushveld igneous activity, and is dated at approximately 2 000 m.y. (Burger and Coetzee, 1973). The Ongeluk Lava, a volcanic unit within the Pretoria Group, has been dated at 2 224 ±24 m.y. (D. Crampton, 1972, pers. comm. to Button, 1976) and this suggests that the dolomites were deposited at about 2 300 m.y.

In essence, Transvaal sedimentation took place upon a generally stable crustal entity known as the Kaapvaal craton which, at this primitive stage in the Earth's history, was not subject to major-orogenic activity. However, large-scale subsidence of this cratonic unit had been continuous and consistent, enabling an enormous thickness of relatively undeformed sediments to accumulate upon it, but, throughout time, tectonic features had been operative which modified and influenced the depositional environments. These structures were mostly inactive during the sedimentation of the Malmani dolomite, but minor tectonic elements did operate in the Carletonville area, displaying predominantly north-south trends.

Topographically, the area is dominated by several east-west-striking, low ridges, composed of the more resistant arenaceous deposits, chert breccia, and dolerite. All scarp slopes face northwards, and the ridges are rarely more than 120 metres above the intervening valleys. The dolomite terrane, to the north of the ridges, is invariably flat and featureless, however, sinkholes of all shapes and sizes are common, and the Carletonville is noted for the disastrous sinkhole collapse which took place in the early sixties, caused by de-watering during mining operations.



re 7 : *The location of the boreholes used in this study.*



Figure 7 : The location of the boreholes used in this study.



Figure 7 : The location of the boreholes used in this study.

E. NATURE OF RESEARCH

1. Introduction

The principal objective of this study was to examine and interpret the geology of the Malmani Dolomite Subgroup, as developed in the subsurface, on the Western Deep Levels and Elandsrand Gold Mine properties. Consequently, the first stage of the investigation involved the selection of the borehole material. In order to conduct a stratigraphic analysis, it was important to try and achieve good aerial distribution of control points, but the choice of boreholes was somewhat limited by the fact that core from many of the earlier drilled holes was either missing, or unlabelled. Ultimately, 17 boreholes were logged between May and October, 1979, representing an accumulated dolomite thickness of over 21 000 metres. Depth data was collected for 24 boreholes from the Geology Department, at the Western Deep Levels Gold Mine, and are presented in Appendix 2. The location of these 24 boreholes is shown in Figure 7.

2. Logging methods

During the logging of the core, a hand-lens-assisted visual inspection was made, and as many physical parameters as possible were recorded on log-sheets, including sedimentary structures, dolomite grain-size, colour, chert content, nature of lithological contacts, and the amount of carbonaceous mudstone and clastic sediment. Tests were carried out at regular 10 metre intervals, using dilute hydrochloric acid, to detect primary limestone, and the percentage-chert content was estimated over lengths of up to 20 metres. However, as the evaluation of chert was extremely difficult, due to the fact that silica is often finely disseminated within the dolomite, this subjective quantitative method was discontinued.

Over several sections of core an attempt was made to extract specific facies information which could be used for Markov analysis. The Markov chain analysis is an objective, statistical method of treating random, sedimentary processes in vertically ordered facies, and interpreting their interdependence and palaeoenvironmental significance. However, unlike other sedimentary rocks, the Malmani dolomite has been subjected to diagenetic dolomitization and silification processes which have, in many cases, drastically modified the

primary rock fabric. This frequently prevents the ready recognition of primary and secondary facies and obliterates parts of the sedimentary cycles. For this reason, it was difficult to select sedimentary facies data which reflected the primary lithological inter-relationships, and this method of analysis was not applied to the carbonates.

3. Thin-sections

After a short time, seven distinctive subdivisions were recognised in the dolomite stratigraphy, and it was evident that there existed a wide range of lithological components. A total of 126 samples was selected from the many different lithologies for petrographic analysis, so that the microscopic characteristics of the dolomites could be examined. Several of these samples were polished and laquered to reveal the macroscopic features. Staining of the dolomite was attempted by using titan yellow, but this only slightly enhanced the dolomite fabric. The catalogue of the thin-sections is presented in Appendix 3.

4. Polished-sections

Twenty polished-thin-sections were prepared for microprobe analysis, to investigate element distribution patterns within the dolomite and to try and detect remnant sulphate in length-slow chalcedony spherulites. For this purpose, a J X A - 5A electron microprobe, at the Anglo American Research Laboratories, was used. Twelve polished-sections of dolomite and carbonaceous mudstone, containing pyrite, were also probed for trace-elements.

5. Geochemical programme

From the first boreholes logged, 40 geochemical samples were taken, representing the main lithological varieties, and these were analysed for 12 major elements and 16 trace elements, at the Anglo American Research Laboratories. The results from this pilot study did not suggest any significant element variation between the dolomite zones, and so it was decided to inspect the vertical element distribution within the stratigraphy by selecting a further 110 samples from Borehole UD30. Approximately 250 grammes of rock

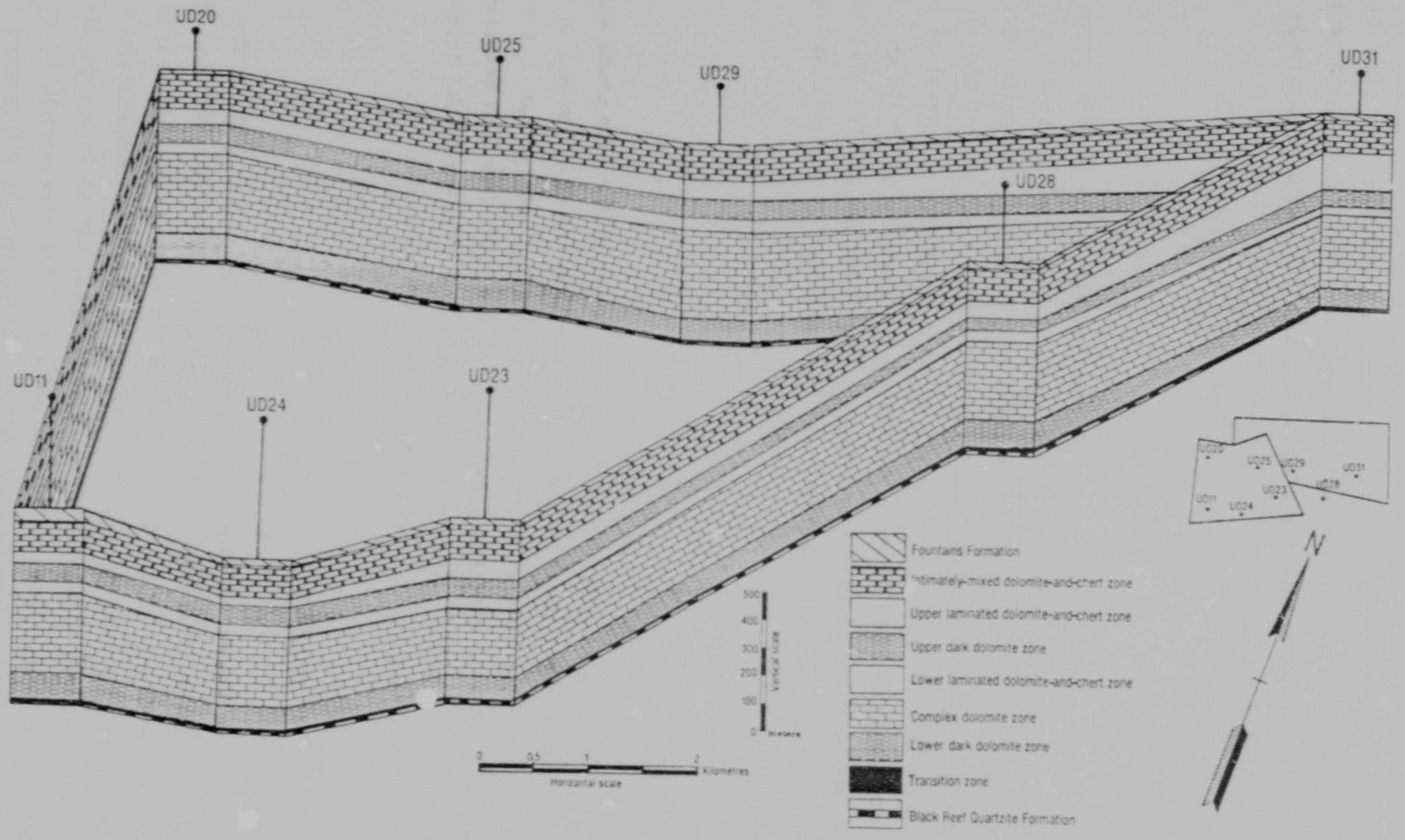


Figure 8 : Isometric stratigraphic diagram illustrating correlation of the Malmani Dolomite Subgroup subdivisions within boreholes examined on the Western Deep Levels/Elandsrand Gold Mine properties.

were taken from each sample by halving the core on a diamond saw. The sample numbers and geochemical data are presented in Appendices 4, 5, and 6. Three carbonaceous mudstone samples, weighing approximately 1 kilogramme each, were taken from three mudstone horizons within the dolomite stratigraphy and analysed by the Bureau of Standards in Pretoria, and by the Soekor laboratories in Johannesburg, to ascertain the nature of the carbonaceous material. The results are shown in Chapter III.

6. Presentation and treatment of data

After the first 8 boreholes had been logged, the stratigraphic details were compared and correlated on a broad-scale, using an isometric, stratigraphic diagram (Figure 8). The major zonal subdivisions appeared to display little, lateral variation. Once depth data and thickness had been compiled (Table 1), it was decided to construct stratigraphic maps in order to reveal contemporaneous tectonism and areas of structural growth within the dolomites. Isopach maps were used to illustrate lateral thickness variations. It was considered that, since the stratigraphic components of the dolomites were similar in lithological composition, variation in thickness was not a result of differential compaction but, rather, due to local structural growth. Structure contour maps were also drawn using a datum of both 1 828,74 metres above sea level, which is the survey datum used at the mine, and the base of the Upper Dark Dolomite Zone, which represents a distinct facies change in the palaeoenvironment. The latter was also used as datum in the construction of panel-diagrams. Since, only 24 data points could be utilized, all the stratigraphic maps have been hand-contoured. None of the depth values used in the compilation of the structure contour maps were corrected for regional dip, since this was not greater than 10 degrees to the south and the structure superimposed on the Transvaal rocks, in the study-area, is simple.

The stratigraphic data indicated the activity of several negative and positive tectonic elements, which operated during sedimentation of the carbonates, and these are defined, in this dissertation, as synformal and antiformal features, respectively. This implies the presence of structures which caused an increase or decrease in the thickness of the sediments through contemporaneous tectonism.

TABLE 1 : STATISTICAL TREATMENT AND SUMMARY OF BOREHOLE DATA, SHOWING THICKNESS OF ZONES, ARITHMETIC MEAN AND STANDARD DEVIATION DERIVATIVES

Stratigraphic Horizon	UO Borehole Number															No. of Data	Mean in Metres	Standard Deviation in Thickness
	11	13	18	19	20	22	23	24	25	26	27	28	29	30	31			
Fountains Formation	92	42	88	48	31	32	24	50	41	43	33	36	33	48	25	15	44,4	19,49
Intimately-Mixed Dolomite-and-Chert	229	273	173	227	273	201	254	234	235	240	306	233	212	176	242	15	233,8	34,11
Upper Laminated Dolomite-and-Chert	80	113	131	152	111	179	163	52	126	125	189	124	137	177	193	15	145,9	52,28
Upper Dark Dolomite	145	123	121	148	147	141	155	143	124	140	155	93	142	138	137	15	136,8	15,41
Lower Laminated Dolomite-and-Chert	86	75	70	88	79	63	82	86	103	51	52	90	80	87	35	15	75,1	17,37
Complex Dolomite	572	590	630	545	570	636	496	496	509	555	558	574	619	569	517	15	562,4	43,50
Lower Dark Dolomite	182	154	194	185	188	178	133	173	205	192	184	226	171	194	142	15	183,4	19,10
Transition Zone	10	29	7	10	2	11	6	18	15	15	17	13	10	21	26	15	13,7	7,12
Black Reef Quartzite Formation	3	11	3	6	5	10	6	3	11	10	0	20	17	2	0	15	7,1	5,13
Total	1 399	1 410	1 417	1 409	1 406	1 451	1 369	1 255	1 369	1 371	1 494	1 409	1 421	1 412	1 317	15	1 393	53,38

The geochemical data were plotted onto vertical distribution diagrams to illustrate the major- and trace-element variations. Several other graphical methods were used to try and detect significant trends and relationships, including ternary and binary diagrams. The single most obvious influence on the element concentrations was a direct sympathetic relationship with silica, and increasing silicification was mirrored by a decrease in the other elements. The CaO/MgO ratio was also calculated and showed that the dolomites have an almost ideal CaO/MgO ratio for dolomite. However, during silicification, CaO is removed to a greater degree than MgO, and the ratio is invariably less than the theoretical value. The average geochemistry for the Malmani dolomites has been compared with that calculated for an average dolomite of various authors.

Finally, since sedimentary carbonate rocks are often the host to base-metal mineralization, an attempt has been made to use all the data in examining the economic potential of the Malmani dolomite.

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CHAPTER II

The Geology of the Malmani Dolomite Subgroup

II. THE GEOLOGY OF THE MALMANI DOLOMITE SUBGROUP

A. INTRODUCTION

Borehole core is ideal for the purpose of lithologic and stratigraphic analysis of the dolomite since all the material is fresh, and, apart from minor core-loss, each borehole contains a complete stratigraphic sequence. At first glance, it is difficult to identify the abundant textures and sedimentary structures present within the dolomite, however, when the core is wetted, these stand-out quite plainly. In the initial stages of logging and data collection, as many physical features as possible were recorded, including colour, dolomite grain-size, chert content, sedimentary structures and stromatolite morphology. After only a short time, several distinctive lithologies were noted, and it was appreciated that the small-scale, detailed relationships between the dark- and light-coloured dolomite and chert, were of fundamental importance. It is on the basis of these observations that the stratigraphic subdivisions have been made.

The Malmani Dolomite Subgroup in the Carletonville area, can be readily subdivided into seven zones (Figure 9), and in order to be consistent with the codes of lithostratigraphic nomenclature, all the subdivisions are given informal rank status and called "zones". This term does not require a geographical qualifier, and, as terminology in this dissertation reflects lithological characteristics, these zones may be applied to problems of regional stratigraphic correlation.

B. SUMMARY OF THE STRATIGRAPHIC ZONES DEVELOPED WITHIN THE MALMANI DOLOMITE SUBGROUP

The base of the dolomites, immediately above the Black Reef Quartzite Formation, consists of the mudstones and dolomicrites of the Transition Zone, and this is overlain by the Lower Dark Dolomite Zone, which is essentially chert-free. This is in turn overlain by the Complex Dolomite Zone, composed of a wide variety of dolomite lithologies, which are laterally impersistent and difficult to correlate. Chert is common throughout, apart from minor exceptions, and this zone grades upwards into the Lower Laminated Dolomite-

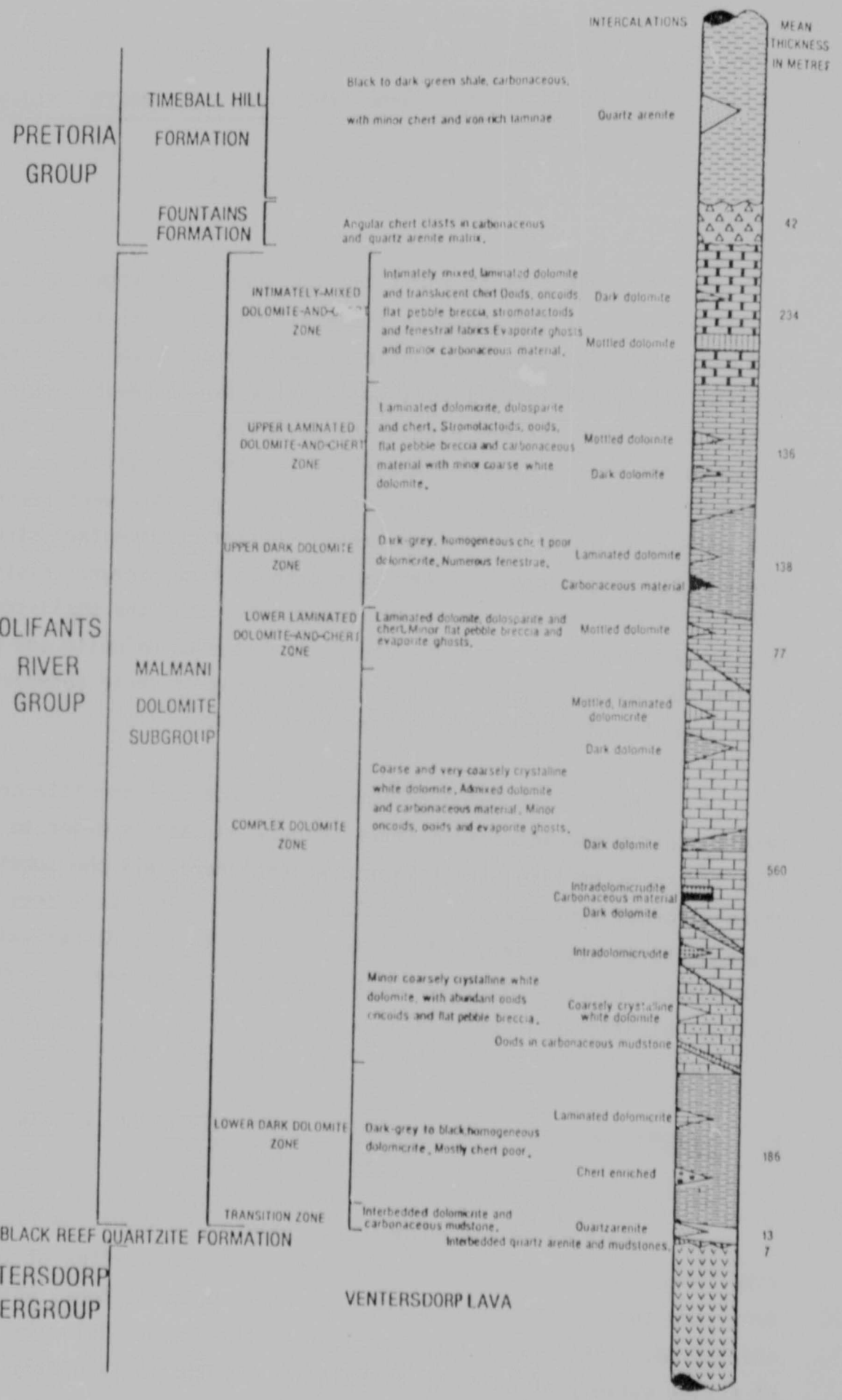


Figure 9 : The descriptive stratigraphy of the Transvaal Supergroup in the Carletonville area, showing the zonal subdivisions made within the Malmani dolomite.

and-Chert Zone. This is followed by the very distinctive Upper Dark Dolomite Zone, which grades into the Upper Laminated Dolomite-and-Chert Zone. The Intimately-Mixed Dolomite-and-Chert Zone marks the top of the dolomite stratigraphy, which is finally capped, in this area, by the Fountains Formation, representing the base of the Pretoria Group.

C. PREVIOUS WORK

Geological exploration on the West Rand has been almost entirely concerned with the gold-bearing deposits in the Witwatersrand Supergroup, and, consequently, the dolomites have received much less attention. However, in the early history of the Transvaal, they were widely prospected because of the stratiform gold-quartz deposits discovered in the Pilgrim's Rest-Sabie district. These small and sporadic occurrences stimulated interest in the Malmani district from which the dolomites take their name, in the Western Transvaal.

The term Dolomite Series was the first officially adopted classification of the dolomites, and this was subdivided into the Lower Dolomite Stage, the Banded Ironstone Stage, and the Upper Dolomite Stage. In 1964, the first meaningful lithological subdivisions were made by Zietsman who recognized six zones (Table 2). Button (1973) developed the old terminology

TABLE 2 : SUBDIVISION OF THE MALMANI DOLOMITE IN THE PILGRIMS REST AREA (AFTER ZIETSMAN, 1964, FROM BUTTON, 1973)

Zone	Thickness (feet-metres)	Summary of Features
6	350 - 107	Shale and dolomite (chert-poor, occasionally oölitic.
5	800 - 244	Dolomite, abundant chert; two internal markers, the "beehive chert" (a stromatolite) and the "middle chert marker".
4	350 - 107	Between the middle shales and the slate marker, mainly dolomite and abundant chert. Includes the bread-and-butter dolomite at top.
3	200 - 61	Incorporates the middle shales and associated dolomite and chert.
2	350 - 107	Dark dolomite, little chert. Rests on Blyde River Quartzite.
1	1 000 - 305	Interval from Black Reef to Blyde River Quartzite; includes the basal transition zone, dark (manganese-rich) dolomite and chert.

TABLE 4 : CORRELATION OF ZONES AND FORMATIONS DEVELOPED IN THE MALMANI DOLOMITE SUBGROUP IN THE CENTRAL TRANSVAAL

NORTHEASTERN TRANSVAAL BUTTON (1973)		CARLETONVILLE AREA THIS THESIS		SWARTKOPS AREA ERIKSSON AND TRUSWELL (1974)		POTCHEFSTROOM AREA ERIKSSON (1971)	
Zone	Thickness Metres	Zone	Thickness Metres	Formation	Thickness Metres		Thickness Metres
Mixed Zone	346	Intimately-Mixed Dolomite-and-Chert Zone	234	Hennops River Formation	388	Chert-Domical Stromatolite Zone	350
- ? - ? - ? - ? - ? -							
Upper Dolomite-and-Chert Zone	366	Upper Laminated Dolomite-and-Chert Zone	136				
UPPER CHERT-POOR ZONE	133	Upper Dark Dolomite Zone	138	Lyttleton Formation	155	Upper Dark Dolomite Zone	160
Lower Dolomite-and-Chert Zone	500	Lower Laminated Dolomite-and-Chert Zone	77	Crocodile River Formation	154	Finely-Bedded Domical Stromatolite Zone Upper Mottled Zone Recrystallized Cherty Zone Lower Mottled Zone Mixed Zone	270
		Complex Dolomite Zone	560	Zwartkrans Formation	269		
				Rietspruit Formation	41	Columnar Stromatolite Zone	110
				Tweefontein Formation	163	Domical Stromatolite-Oolite Zone	160
				Rietfontein Formation	82		
LOWER CHERT-POOR ZONE	<100	Lower Dark Dolomite Zone	186	Oaktree Formation	176	Lower Dark Dolomite Zone	160
Transition Zone	39	Transition Zone	13				
Black Reef Quartzite	up to 500	Black Reef Quartzite Formation	7	Black Reef Formation	24	Kromdraai Member	2-30

of Zietsman (1964), and subdivided the dolomites on the basis of chert content and dolomite colour. Informal stratigraphical terms were adopted, and zones were recognised within the Malmani Dolomite Formation (Table 3). Similar

TABLE 3 : SUBDIVISION OF THE MALMANI DOLOMITE FORMATION (AFTER BUTTON, 1973).

Zone	Thickness in Metres	Stratigraphic Unit
6	33	Mixed Zone
5	407	Upper Dolomite-and-Chert Zone
4	123	Middle Chert-poor Zone
3	401	Lower Dolomite-and-Chert Zone
2	80	Lower Chert-poor Zone
1	88	Transition Zone

subdivisions had been made by Eriksson (1971), in the Potchefstroom area, however, in 1974, Eriksson and Truswell developed a formal classification for subdividing the carbonates, and the rank status of the Malmani dolomite was raised from "Formation" to Subgroup. The different stratigraphic systems are compared, in Table 4, with that developed in this dissertation. A review of much of the early work carried out on the Malmani dolomite has been presented by Button (1973).

D. STRUCTURAL SETTING OF THE MALMANI DOLOMITE SUBGROUP

The regional distribution of the Malmani dolomite in southern Africa, and its northern Cape equivalent, the Campbell Rand Formation, has been illustrated in Figure 5. A detailed structural analysis of the Potchefstroom Synclinorium, which incorporates the study-area, was made by Eriksson (1971), and the major tectonic elements existing before, during, and after sedimentation of the dolomite are shown in Figure 10. Prior to the development of the Malmani sea, several important structures had influenced the sedimentation and tectonic setting of the pre-Transvaal rocks. These included the Ottosdal Anticline, Hartbeesfontein Anticline, and the Johannesburg and Vredefort domes, in the area investigated by Eriksson (1971). These features were relatively inactive during the deposition of the carbonates which was a

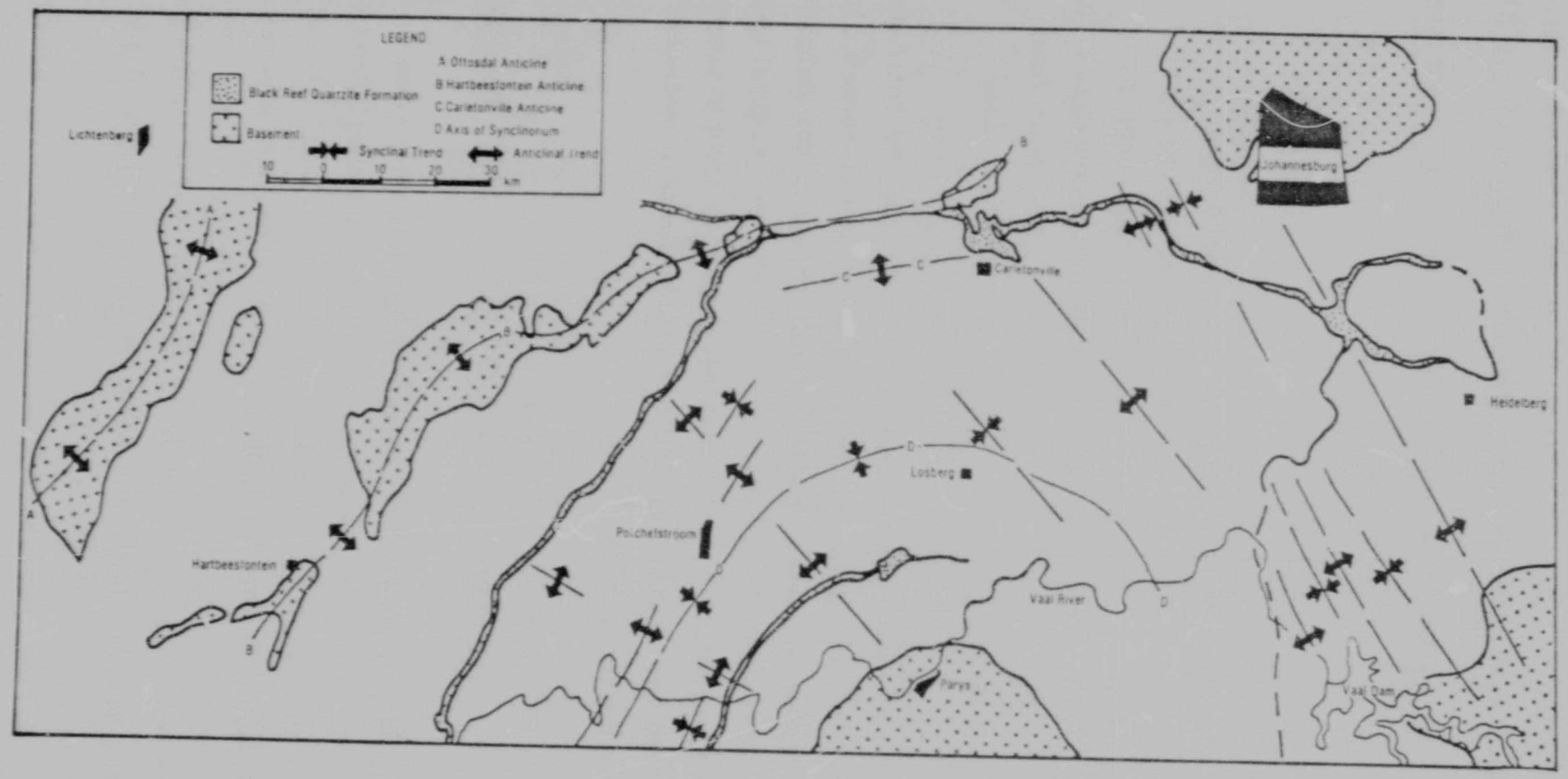


Figure 10 : Main tectonic elements within the Transvaal Supergroup in the area around Potchefstroom (after Eriksson, 1971).

period of tectonic quiescence and stability. The main axis of the Transvaal basin was aligned in an east-north-east direction, which is similar to the principal tectonic overprint which has also been recorded in the pre-Transvaal rocks, and, it has been suggested that, within the Kaapvaal craton, certain structural elements, once generated, have remained active from Witwatersrand times through to the Karoo (Pretorius, 1979). The elements were defined from isopach data and were first noted by Brock and Pretorius (1964).

Eriksson (1971) showed that, in the Potchefstroom Synclinorium, the Malmani dolomite thickens from 500 metres, south-east of Johannesburg, to 1500 metres in the vicinity of Potchefstroom. However, the regional palaeoslope dipped to the north-west during the sedimentation of the carbonates. Eriksson (1971) also postulated that a linear axis of deposition existed, trending north-east through Potchefstroom, and this parallels the Potchefstroom Synclinorium which was probably active at this stage. Eriksson (1971) concluded that, during the deposition of the dolomites, tectonic activity was at a minimum, as would be expected in a carbonate shelf environment, and was surrounded by topographically subdued provenance-areas. However, the total-thickness isopach map of the Malmani dolomite, deduced from the study-area, suggests the presence of two north-north-easterly trends (Figure 11), and shows a thickening of the dolomites on the Elandsrand Gold

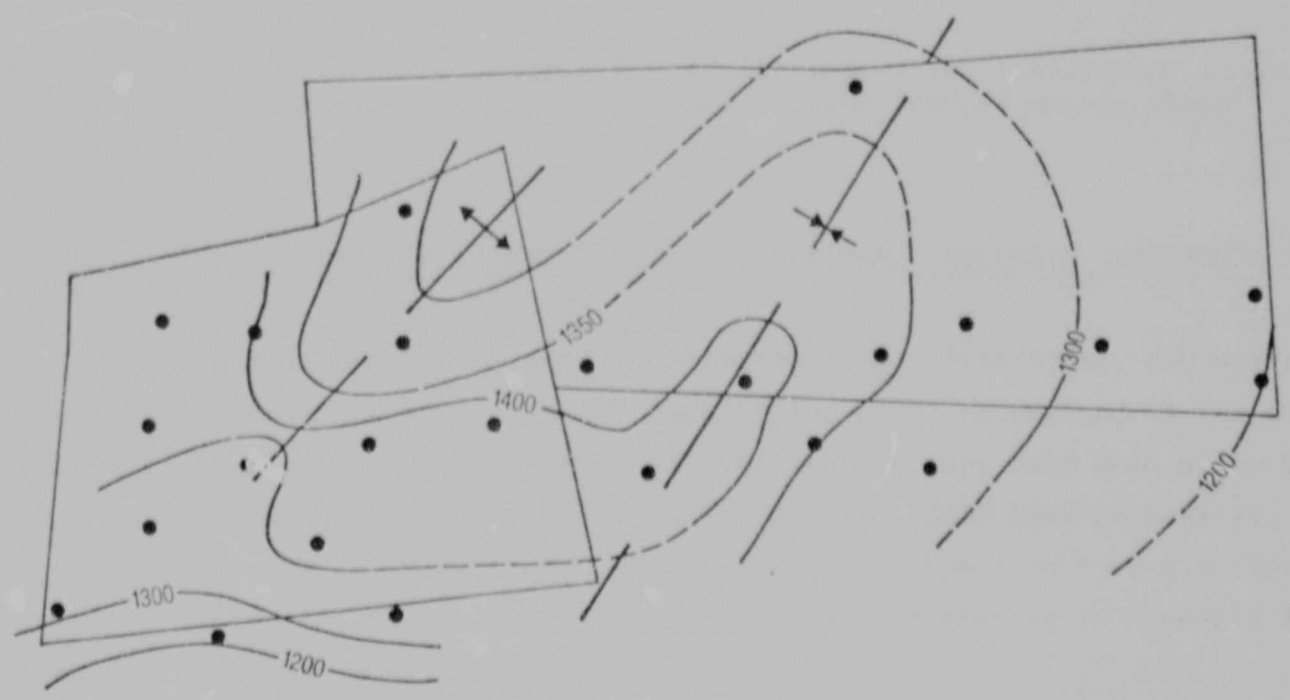


Figure 11 : An isopach map of the Malmani dolomite. Contour interval 100 metres.

Mine property along an east-west axis. The structure contour map of the floor of the Malmani dolomite, represented by the top of the Ventersdorp lavas (Figure 12), reveals a further two north-trending features, including a synform in the east, and an antiform in the west. Although these latter structures are not coincident with the total-thickness map, they do appear to have operated throughout the deposition of the dolomites. These structures do not, however, necessarily mirror pre-existing phenomena. Sedimentologic and stratigraphic evidence for syn-depositional tectonic activity is examined in the following chapter.

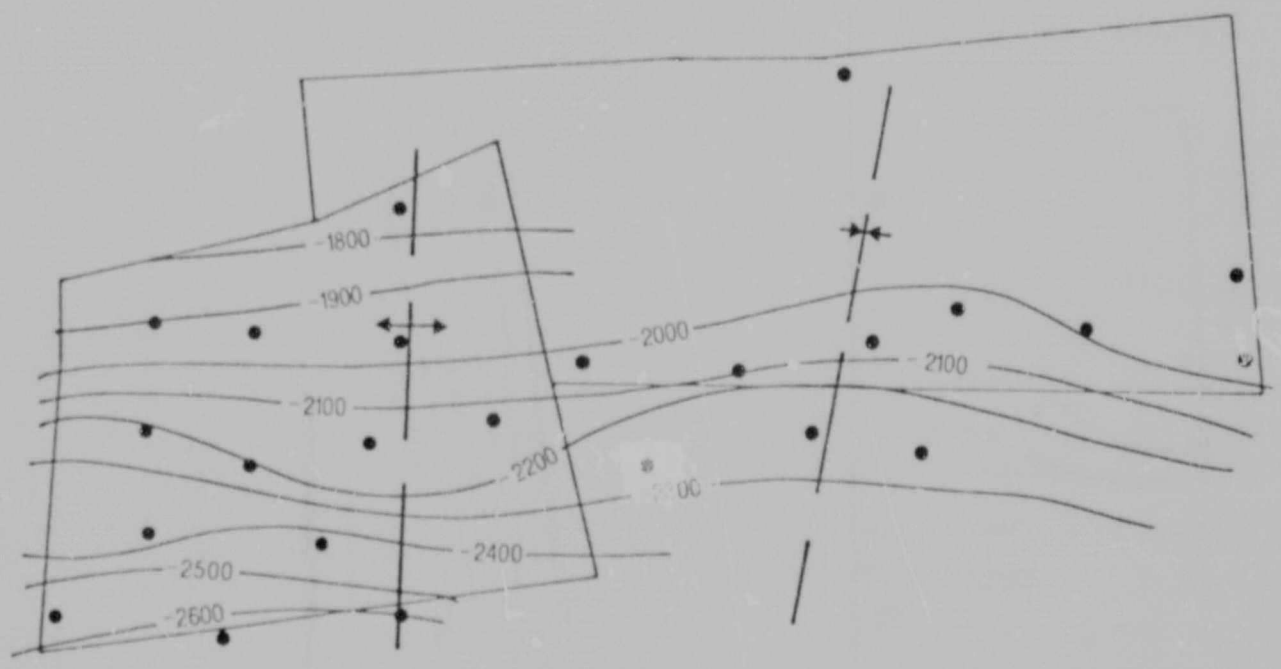


Figure 12 : A structure contour map of the top of the Ventersdorp lavas. Contour interval 100 metres. Datum 1828,74 metres above sea level.

E. DESCRIPTIVE STRATIGRAPHY OF THE MALMANI DOLOMITE SUBGROUP

In this section a detailed stratigraphic, lithologic, and petrographic description is presented for each of the zones recognised in the subsurface of the Carletonville area. All the isopach maps have been drawn on a base map of the Western Deep Levels and Elandsrand Gold Mine properties, as shown in Figure 7. Many terms are used which are specific to sedimentary carbonate rocks, and,for this reason, a glossary is presented in Appendix 1, which defines these words.

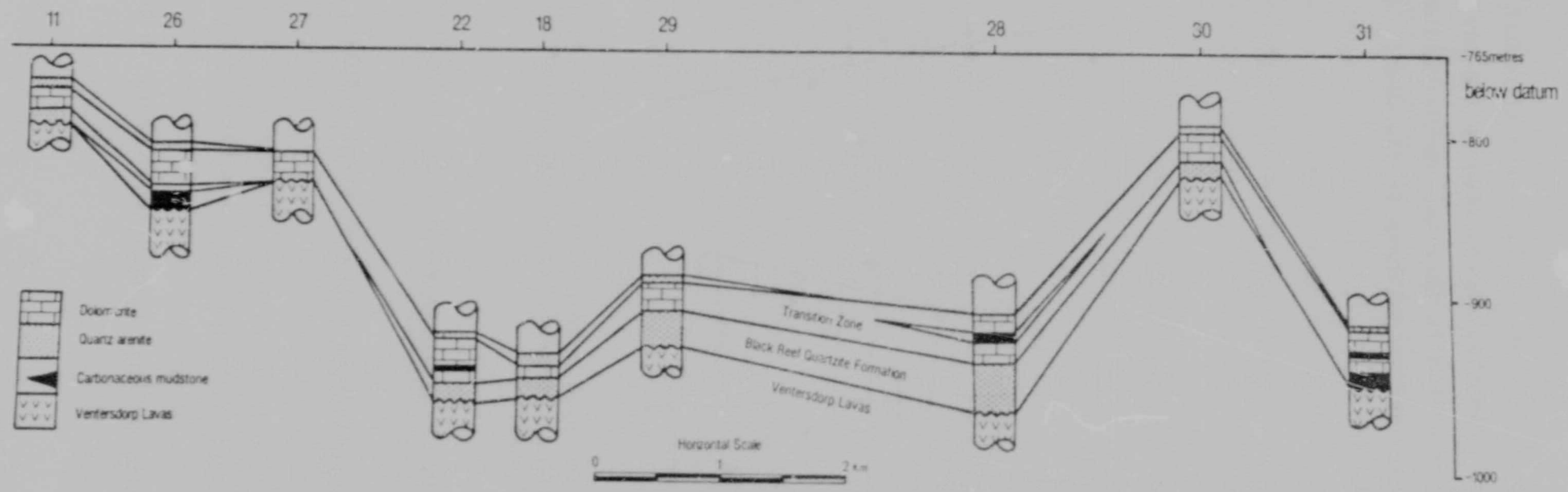


Figure 13 : A stratigraphic panel-diagram illustrating the lateral variation of the Black Reef Quartzite Formation and the Transition Zone.

F. TRANSITION ZONE

1. Introduction

The Transition Zone is diffucult to delineate, since it displays gradational lithologic relationships with the Lower Dark Dolomite Zone, and the Black Reef Quartzite Formation. This difficulty was recognized by Button (1973), in the eastern Transvaal, and, as has been adopted here, the base is placed at the first distinctive dolomite horizon, above the Black Reef. The stratigraphic panel-diagram (Figure 13), illustrates the lateral variation of the Transition Zone, and the isopach map (Figure 14), displays



Figure 14 : An isopach map of the Transition Zone. Contour intervals 5 metres.

the aerial distribution, and reveals a series of east-west-striking contours which swing southwards in the west. There is an increase in the thickness of the sediments in the north-east and south-west, and in several channel-like features, trending east-west.

Black carbonaceous mudstone is the dominant lithological component of the Transition Zone. It is an extremely hard, brittle, black rock, which displays a distinctive slaty-cleavage parallel to the bedding. Thin lenses of silt are developed, which appear to be cross-bedded, and minor quartz-arenite horizons, which are usually less than 5 centimetres in width, but

occasionally up to 1 metre thick, are intercalated with the mudstones. This is in marked contrast to the eastern Transvaal, where 50 metre-thick quartz arenites were observed by Button (1973). The Transition Zone is characterized by dark-grey-to-black dolomicrite bands, ranging in thickness from less than 5 centimetres to over 50 centimetres. These layers are often intricately laminated with the mudstones, and contacts between them are extremely sharp. This reflects the abrupt changes in physico-chemical conditions in the palaeoenvironment. Sedimentary structures are not common, but include small (less than 5 centimetres), laterally-linked, domal stromatolites and minor oncoids. Elsewhere in the basin, ooids, ripple-marks, and columnar stromatolites have been recorded (Beukes, 1977; Button, 1973).

In thin-section, the carbonaceous mudstone consists of an opaque, black, indeterminate substance, with minute muscovite flakes and quartz grains, less than 5 microns in size, scattered throughout the black matrix. Many of the mica laths are orientated parallel to the bedding and occasionally form small lenses. Diffuse patches of dolomicrite are common, together with small, randomly-distributed, euhedral pyrite cubes. A one metre-thick, olive-green-coloured rock is intercalated within the Transition Zone. It appears to be identical to the Ventersdorp Lavas and is unlike intrusive sills observed in other boreholes. It is extremely fine-grained and homogeneous, and contains small chert-and zeolite-filled amygdales. No evidence of chilling was observed, which would indicate an intrusive origin, and no top-surface weathering phenomena associated with extrusive lavas could be discerned.

Thin bands of intraclastic dolomicrite are developed within the Transition Zone, and consist of numerous angular chert, dolomicrite, and mudstone clasts, which exhibit a wide range of sizes. These fragments are set in a flow-banded, cream-and-grey-coloured, extremely-fine-grained, cherty, dolomicritic matrix. This indicates rapid deposition, and it is considered that these rocks represent lime-mud debris flows.

2. Sedimentology

In this area, the Transition Zone attains a mean thickness of 12,8 metres and is poorly developed. However, in the eastern and north-eastern Transvaal, the average thickness of the zone is 39 metres (Button, 1973), whilst, in the northern Cape Province, it is approximately 45 metres thick and forms

Author Clay A N
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