



ECONOMIC GEOLOGY
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THE STRATIGRAPHIC HISTORY OF THE
MALMANI DOLOMITE IN THE EASTERN AND
NORTHEASTERN TRANSVAAL

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INFORMATION CIRCULAR No. 73

UNIVERSITY OF THE WITWATERSRAND
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by

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ABSTRACT

A systematic study of the Malmani Dolomite stratigraphy in the eastern and north-eastern Transvaal has resulted in the recognition of five regionally persistent lithological units. The units are recognized on the basis of dolomite colour and on the proportion of chert, limestone, banded ironstone, mudstone and quartzite interbedded with the carbonates. Three major depositional cycles are recognizable and are separated by two intraformational disconformities. The surfaces of disconformity are capped by thin bodies of chert-in-shale breccia. The geographic distribution of the five units within the dolomite is controlled primarily by the pre-Pretoria Group unconformity. The Pretoria Group comes to rest upon successively lower units within the dolomite when followed in a southerly direction. Very extensive deposits of primary limestone, hitherto unrecorded in the Transvaal, are described. These bodies represent remnants of a primary limestone which has been all but totally obliterated by the dolomitization process. The limestone deposits are very similar in their stratigraphic setting and in their stratigraphic relationships to the economically exploited deposits of the northwestern Cape Province.

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THE STRATIGRAPHIC HISTORY OF THE MALMANI DOLomite IN THE EASTERN AND NORTHEASTERN TRANSVAAL

INTRODUCTION

The Malmani Dolomite constitutes an economically-important stratigraphic entity, being the host to exploitable deposits of gold, lead, zinc, manganese, pyrite, fluorite, limestone, dolomite and chrysotile asbestos. To a greater or lesser extent, all of these mineral deposits exhibit a degree of stratigraphic control. It follows that the elucidation of the stratigraphy and stratigraphic relationships within the unit is of prime importance in the search for further exploitable mineral deposits. The purpose of this paper is to sketch out the regional stratigraphic features of the Malmani Dolomite in the eastern and northeastern portions of the Transvaal. The conclusions are based exclusively on field observations and represent a synthesis of a large number of measured profiles. It is considered that the relatively large amount of descriptive data presented here is justified by the paucity of previous documentations of dolomite stratigraphy and by the potential value of an understanding of stratigraphy to mineral exploration. The paper has, however, been written in such a fashion that the sections dealing with descriptive stratigraphy can be omitted by readers requiring only a knowledge of generalized stratigraphy and stratigraphic relationships.

GEOLOGICAL SETTING

The area studied, situated in the eastern and northeastern portions of the Transvaal, is outlined in Figure 1. On this map, the outcrop distribution of the Olifants River Group is indicated.

The Malmani Dolomite, a succession of stromatolitic carbonate rocks, with interbedded chert and subordinate shale and quartzite, is developed throughout the Transvaal basin. In the axial portions of the basin, the Malmani is overlain by the Penge Formation (largely banded ironstone) which is in turn covered by the Duitschland Formation (carbonates with clastic sediments). This triad, dominated by chemical-type sedimentation, is referred to here as the Olifants River Group (see Figure 2).

The Olifants River Group is covered by the Pretoria Group (shales with quartzitic and volcanic horizons); it grades downwards to the Black Reef Quartzite, the lowest formation in the Transvaal Supergroup over the major portion of the basin. The Black Reef rests unconformably upon older formations, except in the northeastern Transvaal, where it conformably covers the proto-basinal stage of Transvaal deposition, known as the Wolkberg Group (see Figure 2).

In the area studied, the Transvaal rocks were deposited on a cratonic granite and greenstone basement and are overlain by the mafic intrusives of the Bushveld Complex. The age of the Transvaal Supergroup is likely to fall within the limits of 2100-2300 million years (Davies and others, 1969; van Niekerk and Burger, 1964).

PREVIOUS WORK

A moderately detailed understanding of the Malmani Dolomite stratigraphy in the Pilgrims Rest area was gained towards the end of the last century through the economic stimulus afforded by the gold-quartz orebodies developed in the dolomite. Nicol Brown (1896), Wilson-Moore (1896), Thord-Gray (1905), Von Dessauer (1909), Hall (1910), Bell (1921), Wyberg (1925), Reinecke and Stein (1929), Visser and Verwoerd (1960) and Zietsman (1964) all contributed to an understanding of the dolomite stratigraphy in this rather limited portion of the Transvaal basin. In essence, they recognized a northward-thickening pile (1000 feet

Fig. 1
Location and Regional Geology

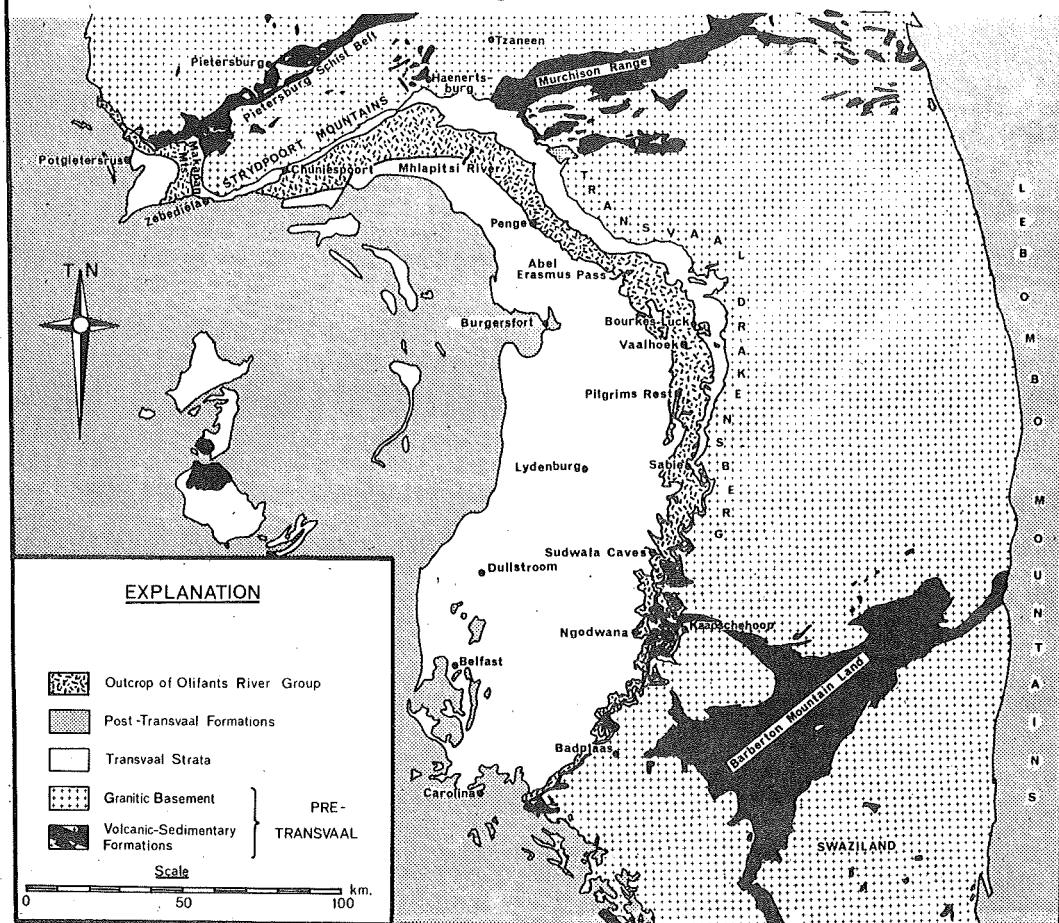
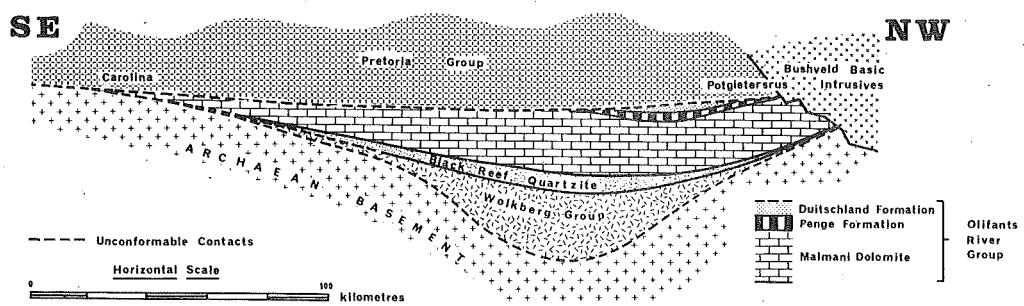


FIG. 2

GROSS STRATIGRAPHIC SUBDIVISION OF THE TRANSVAAL SUPERGROUP, EASTERN AND NORTHERN TRANSVAAL



to 3000 feet) of sediment dominated by dolomite and chert which they referred to as the "Dolomite Series". The dolomite was seen to grade downward to the Black Reef Quartzite through a transitional zone composed of dolomite with beds of shale and quartzite. It was recognized that the dolomite was abruptly terminated by the "Bevets Conglomerate", which was overlain by the lowermost of the "Pretoria Series" shales. Various marker horizons were established within the dolomite; in particular, shale markers were found at 40, 600, 850 and 1100 feet below the top of the dolomite in the Pilgrims Rest area. The lowest of the shale markers rests upon the Blyde River Quartzite, a very distinctive bed traceable over many miles of strike. A chert marker was recognized some 230 feet down from the base of the Pretoria Group. Other stratigraphic markers include a zone poor in chert above the Blyde River Quartzite (Bell, 1921), a stromatolite marker (Zietsman, 1964), and a distinctive alternation of dolomite and chert referred to as the "bread and butter dolomite" (Bell, 1921).

Hall, in 1910, recognized that the "Bevets Conglomerate" (which separates the Pretoria from the "Dolomite Series") represented a depositional hiatus of some importance. Zietsman (1964) showed how this unconformity had a distinct angular component, the "Bevets Conglomerate" coming to rest upon distinctly lower portions of the stratigraphy when traced towards the south.

The "Giant Chert", developed at the top of the "Dolomite Series" had long been regarded as portion of the dolomite stratigraphy. Zietsman (1964) demonstrated that the "Bevets Conglomerate" and its associated quartzite often graded downwards into the "Giant Chert". The latter was shown to transgress the dolomite stratigraphy. The "Giant Chert" (in essence a chert breccia in which the matrix is often poorly manifested) covers an ancient erosional surface in the dolomite and, according to Zietsman, is more logically regarded as the basal unit of the "Pretoria Series".

Further afield, descriptions of dolomite stratigraphy in the area under review are more generalized. Descriptive accounts of the "Dolomite Series" are provided by Kynaston and others (1911), Hall (1912; 1914; 1918), Visser (1956) and Schwellnus and others (1962). It is evident that in areas away from the goldfields at Sabie and Pilgrims Rest, no serious attempts have been made to subdivide the Malmani Dolomite stratigraphy.

The pre-Pretoria Group unconformity recognized by Zietsman in the Pilgrims Rest area was clearly mapped by Schwellnus and others (1962) in the Penge area, further to the north. Here, the equivalent of the "Bevets Conglomerate" eliminates successively lower horizons within the Penge Formation and eventually truncates this formation, coming to rest upon the uppermost units of the Malmani Dolomite to the west of Abel Erasmus Pass.

Descriptions of the Penge Formation are provided by Hall (1930), du Toit (1945), Vermaas (1952), Schwellnus and others (1962) and by Dreyer (1967). From his detailed mapping of a small area, supplemented by a study of borehole cores and underground exposures, Dreyer has compiled the most comprehensive account of the stratigraphy of the Penge Formation in the area studied. The total thickness of the formation is reported to be of the order of 2000 feet in the Bewaarkloof region.

On a basin-wide scale, a few writers have contributed to a regional understanding of the stratigraphic subdivision of the Malmani Dolomite. In 1933, Young described the stratigraphy of the Malmani Dolomite in the Carletonville area, basing his conclusions on observations made on borehole cores. These observations were supplemented by Toens' (1966) description of the stratigraphy in the Klerksdorp and Carletonville areas, again based on a study of boreholes.

The most comprehensive account of the stratigraphy of the Transvaal dolomite is that of Eriksson (1971). On a basis of a detailed study of dolomite cores from the Potchefstroom Synclinorium, Eriksson recognized ten lithological units within the 1200 metre-thick Malmani Dolomite. Many of his zones are recognized on the basis of sedimentary structures or textures. In effect, four gross lithological units are present in the area studied by Eriksson. One of the most significant facts demonstrated by Eriksson was the strong correlation between the colour of the dolomites and their iron and manganese content, dark dolomites being relatively rich in these elements.

THE BASIS OF SUBDIVISION

In the area studied, the subdivision of the dolomite stratigraphy was based primarily on gross lithology. In essence, a recognition of distinctive key beds was integrated with a study of gross lithology to produce the subdivision presented here. In the first category, key beds of mudstone, quartzite, chert-in-shale breccia, chert, limestone and banded iron formation were of importance. In the second group, the type of dolomite and the relative abundance of mudstone, quartzite, chert, limestone and banded ironstone were utilized. While the presence of sedimentary structures was noted, none of the regionally-persistent units in the dolomite was erected on this basis alone. It was felt that the recognition of units based on sedimentary structures would result in zones, which, though possibly of regional extent, would be difficult to map on a regional basis. Regional mapping, which makes use primarily of airphoto patterns for identification of units, relies fundamentally on gross lithology. Thus, the light tone afforded by a dolomite and chert assemblage is of greater value to regional mapping than a diagnostic sedimentary structure which has no detectable response on an airphoto.

TECTONIC FRAMEWORK OF DEPOSITION

An isopach map of the Malmani Dolomite in the eastern and northeastern Transvaal is presented in Figure 3. The gross pattern is one of thickening into the Selati trough (an east-northeasterly-trending floor-tectonic feature developed in the vicinity of the Murchison schist belt). To the south of the trough, thicknesses decrease relatively rapidly to some 600 metres in the Pilgrims Rest area. South of Pilgrims Rest, the unit thins gradually to a minimum of 100 metres in the vicinity of Badplaas. In this region, some palaeotopographic features are of local importance. To the north of Badplaas, a serpentinite spine in the pre-Transvaal basement formed a topographic high, over which the dolomite underwent a marked thinning. According to Visser (1956), this body of serpentinite projects through the dolomite in one locality and is covered directly by the basal unit of the Pretoria Group.

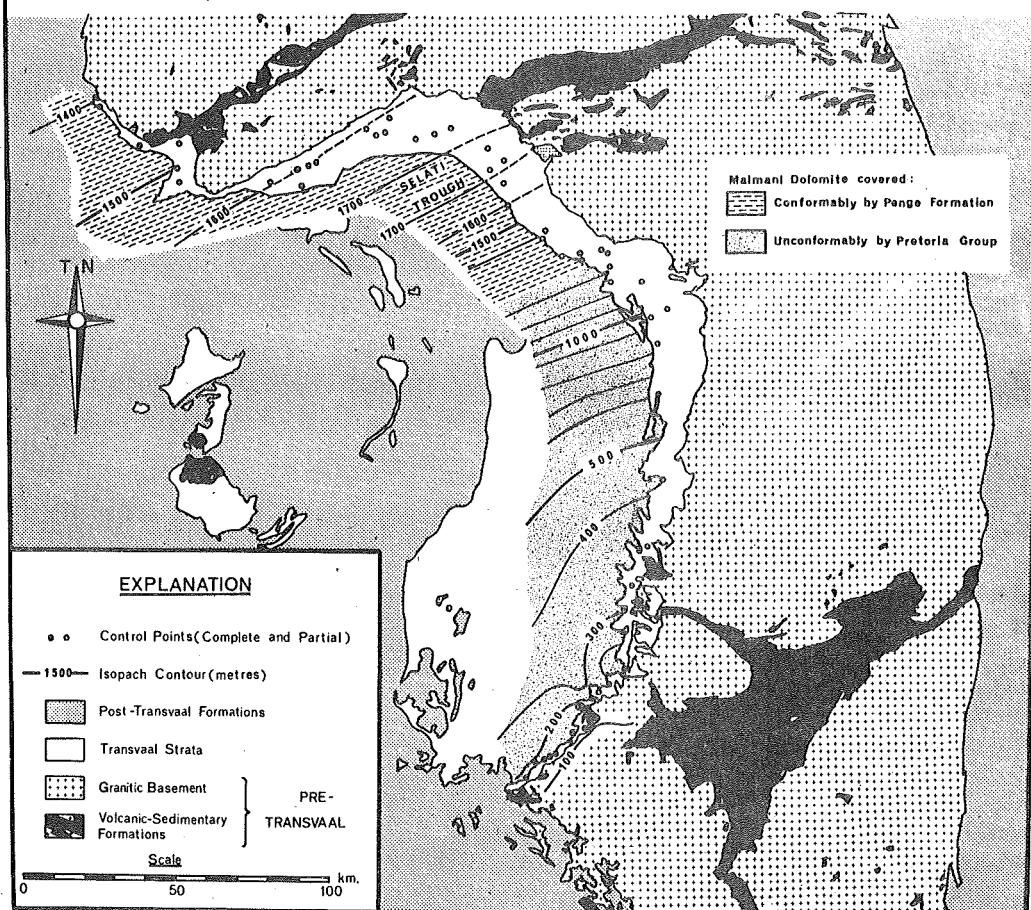
To the north of the Selati trough, a gradual thinning from 1700 to 1400 metres along east-northeast-trending contours is indicated on the isopach map. The thinning is due largely to the diminution in thickness of the basal unit of the Malmani Dolomite (the transition zone) as traced towards the northwest.

The thickness pattern shown in the isopach map is a reflection of syn- and post-depositional tectonics. In particular, the stippled area lying to the south of the Selati trough demarcates that portion of the basin in which the base of the Pretoria Group rests unconformably on the Malmani Dolomite. Here, southerly thinning may be attributed in part to the thinning of individual units within the dolomite, but a far greater factor is the post-depositional uplift and erosion of Malmani Dolomite on the southern basin-flank. In essence, the southern flank of the basin was subjected to a broad, epeirogenic-type uplift which resulted in the erosional truncation of up to 1600 metres of the dolomite stratigraphic pile. In contrast to this basin-flank epeirogeny, the axial portions of the basin suffered intense deformation during pre-Pretoria times. The Olifants River Group (and underlying Black Reef Quartzite and Wolkberg Group) were thrown into a series of folds with east-northeast-trending axes. Erosional truncation of the folds ensued (Schwellnus and others, 1962) and resulted in the Pretoria Group being deposited on various portions of the Olifants River Group stratigraphy when traced along strike.

The changes in basin tectonics with time are illustrated by Figure 4, a "round-the-outcrop" panel diagram of the Malmani Dolomite. The most striking feature shown is the obvious basin-expansion with time, which has resulted in the overstepping relations clearly shown here. The Malmani Dolomite was deposited over a significantly larger area than the Wolkberg Group, its proto-basinal forerunner. The depositional tectonics of the Black Reef and Wolkberg eras are weakly manifested during Malmani deposition. In particular, it is shown that the transition zone and the lower dolomite and chert zone attain their maximum development in the Selati trough region.

Malmani Dolomite - Isopach Map

Fig. 3



In the Potgietersrus area, the rapid pinch-out of the Black Reef Quartzite and the Wolkberg Group has no parallel in the overlying Malmani Dolomite, which maintains near maximum thicknesses as far north as exposures can be followed. It is evident that the northern basin-edge platform, active during Wolkberg and Black Reef times, was not a tectonic feature of note during Malmani times. The basin-edge platform of the Malmani era must have been developed at some significant distance farther north of the northernmost exposures of the Malmani Dolomite.

THE GROSS STRATIGRAPHY AND STRATIGRAPHIC
RELATIONSHIPS OF THE MALMANI DOLOMITE

The Olifants River Group is defined as that stratigraphic unit, dominated by chemical-type sedimentation, which rests upon the Black Reef Quartzite, the Wolkberg Group or the pre-Transvaal basement, and is overlain by the Pretoria Group (Figure 2). In the eastern and northeastern Transvaal, the group is subdivided into the Malmani Dolomite, the Penge Formation and the Duitschland Formation. The Penge and Duitschland formations are best

FIG.4

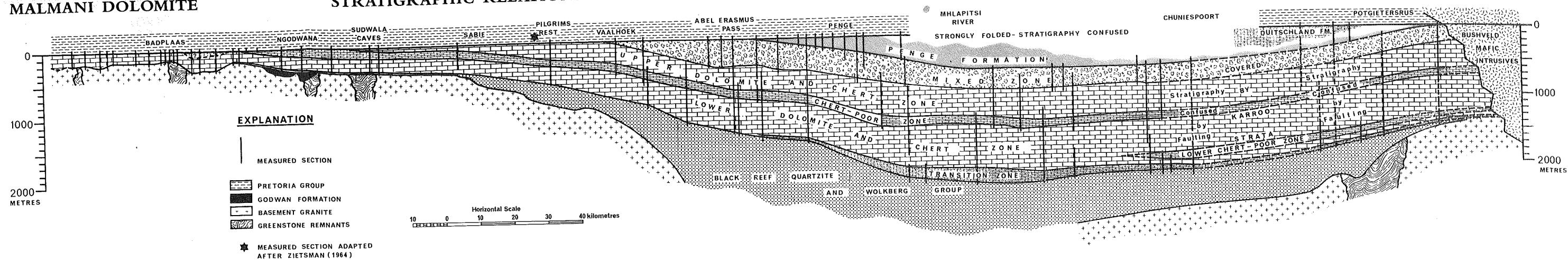
MALMANI DOLOMITE**STRATIGRAPHIC RELATIONSHIPS IN THE EASTERN AND NORTHEASTERN TRANSVAAL**

FIG.5

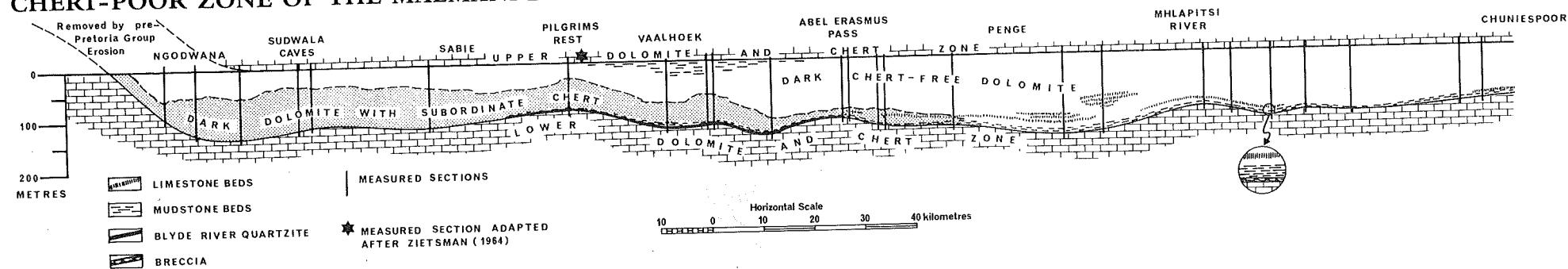
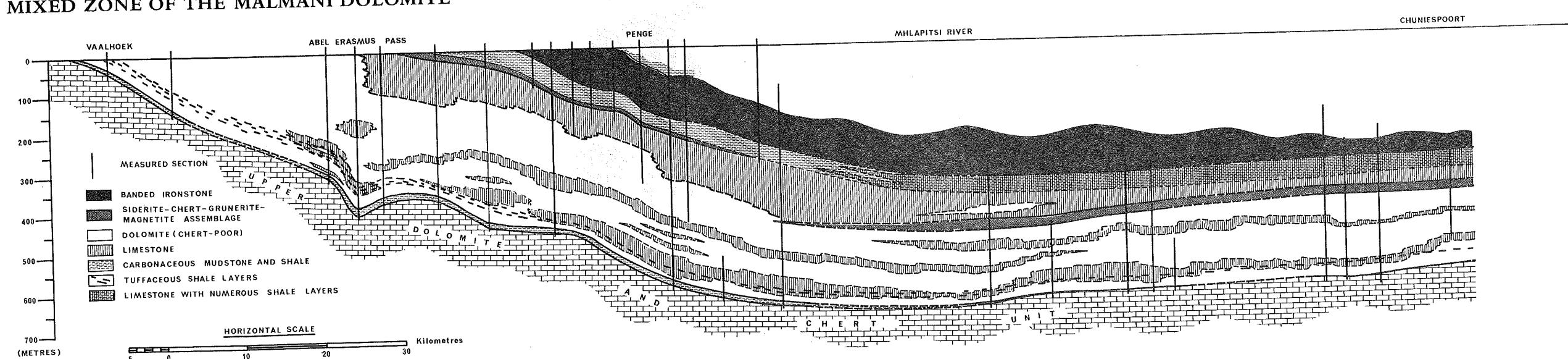
CHERT-POOR ZONE OF THE MALMANI DOLOMITE**AN INTERPRETATION OF STRATIGRAPHIC RELATIONSHIPS**

FIG.6

MIXED ZONE OF THE MALMANI DOLOMITE**AN INTERPRETATION OF STRATIGRAPHIC RELATIONSHIPS**

DESCRIPTIVE STRATIGRAPHY OF THE MALMANI DOLOMITE

In the following section, the details of Malmani Dolomite stratigraphy will be presented in moderate detail. It is felt that, on account of the absence of any other descriptions over comparably large areas, it was worthwhile presenting as full an account of the stratigraphy as was reasonable. The extremely gradual lateral changes which occur in the Malmani Dolomite make it likely that the subdivision proposed here could be applied on a basin-wide scale.

A. THE TRANSITION ZONE

In general terms, the transition zone is defined by the relative abundance of clastic sediments (quartzite and carbonaceous mudstone), the dark colour of the interbedded dolomite and the paucity of chert. It attains its greatest development in the Selati trough region, where thicknesses of up to 200 metres have been recorded. The zone thins to the north and south of this region; south of the Abel Erasmus Pass, thicknesses of less than 20 metres were measured, so that the unit was not shown separately on the panel-diagram presented in Figure 4.

The dolomite of the transition zone, due to the relatively high amounts of contained iron and manganese, weathers with a chocolate-brown surface. Where fresh, it is grey or dark grey. The dolomite was observed to carry scattered quartz grains on occasion and, where thermally metamorphosed, some mica flakes. Sedimentary structures seen in the dolomite include ripple marks, oölites (rare), and various types of algal structure. Crinkly algal lamination is almost universally seen; lateral-linked domes with diameters of 10 to 20 centimetres are common. Some of the latter were evidently smothered by shale deposition, since their upper surface is sharply terminated by shale beds draped over the stromatolite domes. In rare instances, small linked columnar stromatolites were seen.

Quartzite layers are interbedded in the transition zone and may attain thicknesses of up to 50 metres, although beds in the metre-to-5-metre thickness range are more common. In composition, the quartzites are fairly pure, but felspathic, carbonaceous and argillaceous varieties are represented. In the vicinity of the Selati trough, some of the thicker quartzite bodies carry thin beds of small and medium quartz-pebble conglomerate. Gritty horizons are more universally developed in the quartzites of the transition zone. The quartzites are often carbonate-bearing and, where fresh, pyritic cubes and stringers have been observed. On weathering, the carbonates and sulphides alter to the limonitic specks which typify the quartzites of this unit.

The transition zone quartzites are usually cross-bedded, with both trough and planar types being represented. Trough units seldom exceed 20 centimetres in thickness, but planar units up to 50 centimetres thick are common. The small amount of palaeocurrent work carried out on cross-beds of this unit has shown a very wide spread of foreset azimuths.

Beds of black carbonaceous mudstone and shale are universally developed in the transition zone. In places, these argillaceous rocks show a differentiation of grain-sizes into lighter coloured silty layers and darker shaly layers, but in general they are very poorly bedded. Ripple marking on bedding surfaces is the only sedimentary structure of note. Rock-types transitional between the mudstones and quartzites are developed in places. These include quartz-wacke rocks (quartz grains in a mudstone matrix), siltstones and argillaceous quartzites.

B. THE LOWER CHERT-POOR ZONE

Within the lower dolomite and chert zone (Figure 4), a chert-poor unit was consistently encountered in measured sections between Chuniespoort and Potgietersrus. The zone appears to pinch out east of Chuniespoort; northwest of Potgietersrus, its relationships are obscured by the metamorphic and structural complexities produced by the Bushveld intrusions. Measured thicknesses range from about 50 to 110 metres, an average of 80 metres having been calculated for the unit.

The lower chert-poor zone bears a strong resemblance to the transition zone described above. It is characterized by chocolate-brown-weathering dolomite or calcareous dolomite which, on fresh surfaces, is dark grey to black in colour. The dolomite is finely crystalline and, where metamorphosed, carries scattered flakes of mica.

Up to three quartzite beds are usually developed in the unit, one of them sharply demarcating the base of the zone. The beds of quartzite seldom exceed a metre in thickness; they are medium-grained (rarely gritty) and are limonitic-speckled. They are pure to slightly felspathic in composition and very often carry carbonate minerals. Ripple-marking and trough cross-bedding typify these quartzites. Black carbonaceous shales and mudstones are common in the unit and are present in beds which vary in thickness from a few millimetres to metre-dimensions.

The carbonate rocks exhibit algal lamination and lateral-linked domical stromatolites with diameters ranging from 30 centimetres to a metre. These are often draped by centimetre-thick shale beds. In one instance, stacked columnar stromatolites with diameters of 5 centimetres and column-heights of 20 centimetres were observed in this unit.

C. THE LOWER DOLOMITE AND CHERT ZONE

The lower dolomite and chert unit is developed throughout the eastern and north-eastern sectors of the Transvaal basin. Along the Selati trough and north thereof, thicknesses of up to 650 metres have been recorded. The unit thins steadily to the south and, in the Ngodwana area, is reduced in thickness to about 190 metres. An average thickness of 400 metres has been calculated for this unit.

The lower dolomite and chert zone is characterized by the abundance of chert and by the light colour of the associated dolomite. The dolomite is generally light grey in colour; where recrystallized, it is usually white. The dolomite weathers with a light grey surface. Adjacent to major fault systems, the bedding in the dolomite is often obliterated and the rock assumes a colour which ranges from pink to red.

Chert is present in layers which vary from the most delicate laminae to bars with thicknesses of up to 2 metres. Discontinuous lenticular bodies and replacements which cross-cut the bedding were observed (Plate 1A). Where fresh, the chert is often dark grey to black in colour; on weathering, it bleaches white. In the axial portions of the basin, a sub-zone which extends from about 120 to 230 metres down from the top of the lower dolomite and chert zone is particularly rich in thick bodies of chert. This sub-zone gives rise to a photo-marker typified by a very light tone.

Depending on the degree of exposure and thickness of the lower dolomite and chert zone, from 6 to 14 horizons free or relatively free of chert have been noted in measured sections. Only one was found to have any correlative value. This sub-unit is developed in the basin axial region and for some distance on either side. It consists of 30 to 40 metres of dolomite which is somewhat darker-coloured than is usual for the zone as a whole. It is developed, on the average, about 230 metres below the top of the zone (see Appendix Diagram I). This chert-free unit carries shale beds and, on occasions, preserves small cross-beds and a layer of edgewise conglomerate. It can be confused with the overlying principal chert-poor unit, but is some three times thinner and is composed of somewhat lighter coloured dolomite.

On metamorphism, tremolitic needles and prisms develop in the dolomite. Elsewhere, a temperature-induced reaction of chert and dolomite produces serpentine, the serpentine layers and laminae replacing chert and outlining delicate depositional structures. This is particularly the case in the area northwest of Potgietersrus, where the mafic phase of the Bushveld Complex cuts across the dolomite stratigraphy. In the Badplaas area the numerous sills intrusive into the dolomite have altered the dolomite and chert to a limestone-serpentinite-talc assemblage in which exploitable seams of chrysotile asbestos are found.

Beds of black carbonaceous mudstone are developed throughout the lower dolomite and chert zone, but are particularly abundant in the area around Pilgrims Rest and Sabie. The mudstones carry scattered quartz grains on occasion. Specks of iron oxide derived from the decomposition of pyrite are common. Desiccation cracks have been observed on some bedding

surfaces. Near the base of the unit, some of the mudstones are more in the nature of wacke rocks, consisting of a shale matrix with grains of quartz and felspar together with mica flakes.

Thin beds of impure quartzite (less than 1 metre thick) were encountered in some measured profiles through the lower dolomite and chert zone. These beds are developed locally and are of little use in correlation.

Beds of chert-in-shale breccia were encountered at various levels within the lower dolomite and chert zone. The most persistent occurs at the top of the unit and will be described in the subsequent section. In the area extending from Sabie to Carolina, a bed of chert-in-shale breccia was encountered at an average distance of 80 metres above the Black Reef Quartzite. This bed, which is usually only 1 or 2 metres thick, consists of a black carbonaceous mudstone in which are found fragments of chert and, in many cases, scattered quartz grains and pyrite euhedra. The chert fragments vary in size from small grains to discoid slabs some 30 centimetres in diameter and 5 centimetres thick. The chert slabs are oriented with their long axes lying in the bedding plane (Plate 2B). Within the breccia, alternating layers rich and poor in chert fragments were recorded.

Mechanical sedimentary structures found in the lower dolomite and chert zone include öölites, ripple marks (Plate 1C), interference ripple marks (Plate 1D), climbing ripples and, rarely, beds of edgewise conglomerate. Organo-sedimentary structures are very common, crinkly algal lamination being almost universally developed. Lateral-linked domical stromatolites with diameters varying from 10 centimetres to 2 metres are common. The surfaces of some of the larger domes are ornamented with smaller domes. Cross-sections of some domes show a vague radiating structure. Chevron-shaped stromatolites, linked columnar stromatolites and encapsulated spherical structures were recorded only occasionally.

D. THE CHERT-POOR ZONE

The chert-poor zone forms one of the most useful stratigraphic marker units, being developed throughout the eastern sector of the Transvaal basin from Potgietersrus to south of Ngodwana (Figure 4). The unit maintains a remarkably constant thickness of between 80 and 140 metres. A mean thickness of 123 metres has been calculated from 24 measured sections.

The new cycle of deposition represented by this unit is generally ushered in by the deposition of a bed of chert-in-shale breccia. This rock unit is by no means universally developed, but it has been found in the majority of measured sections between Ngodwana and Potgietersrus. The breccia, which is up to 2 metres thick, consists of angular and ill-sorted chert fragments in a carbonaceous mudstone matrix. The chert fragments are usually plate-like and have their long axes oriented parallel to the plane of stratification. The chert fragments vary in size up to a maximum of about 10 to 50 centimetres. On occasions, the breccia has been found to carry fragments of dolomite.

The breccia described above is succeeded by clastic sediments. In the area between Pilgrims Rest and the Abel Erasmus Pass, a bed of quartzite known as the Blyde River Quartzite is present at this stratigraphic level (Figure 5). The Blyde River Quartzite is overlain and grades laterally to a bed of carbonaceous mudstone.

The quartzite varies in thickness up to a maximum of about 7 metres, but thicknesses in the 2 to 4 metre-range are more usual. It is medium-grained, with locally developed gritty phases. In the Bourkes Luck area, stringers of gritty small-pebble conglomerate were noted. The quartzite is generally fairly pure but is usually mottled white and orange due to the presence, respectively, of a small proportion of felspar grains and iron oxides (derived by the decomposition of pyrite). Trough cross-bed units are found in the quartzite and measure between 10 and 30 centimetres in thickness. The orientation of foreset azimuths measured at one station west of Bourkes Luck indicated a provenance area situated to the northeast.

The Blyde River Quartzite is overlain by a mudstone or a mudstone-dolomite alternation. Where the quartzite is not developed, mudstone is found to rest upon the underlying breccia. In the Pilgrims Rest area, mudstone beds up to a metre thick are developed throughout the chert-poor zone, but are concentrated near the base and the top of the unit. The abundance of shale in the unit decreases both north and south of the Pilgrims Rest area. In the Selati trough region, a 5 to 10 metre-thick mudstone or mudstone-dolomite alternation is found at the base of the unit. Here, thinner shale beds are found upwards in the succession,

but are rare above 20 metres from the base of the unit. The mudstones are black and carbonaceous and are often pyritic. They are often sheared by intrastratal movements. In places, the mudstone was observed to be banded, having been deposited in lighter-coloured silty and darker-coloured shaly bands.

The unit as a whole is characterized by the subordinate rôle of chert and by the dark colour of the dolomite. The dolomite weathers chocolate brown or dark grey; on fresh surfaces it is dark grey in colour. The dolomite is fine-grained crystalline. It carries scattered quartz blebs, and, where thermally metamorphosed, prisms of amphibole and mica flakes are developed. The contact of the chert-poor zone with the overlying unit is gradational over a few metres, the uppermost phases being somewhat lighter coloured, more commonly recrystallized, and carrying more chert than the zone as a whole.

To the north of Penge, chert is entirely absent in this unit. South of this locality, subordinate amounts of chert are present in the basal portions of the unit. As the zone is traced farther south, chert is found in the unit at successively higher stratigraphic levels (Figure 5). In general, the chert developed in the unit is present in thin, discontinuous lens-like layers (Plate 1E).

To the north of the Abel Erasmus Pass, limestone is often encountered in the basal portion of the chert-poor zone. Usually only one bed of limestone with a thickness of less than 5 metres is present (Figure 5). In the region of the Selati trough, more than one bed of limestone is found. The limestone weathers grey, it tends to be more crystalline than the surrounding dolomite. The thin shale beds developed in the limestone are often ptygmatically folded. The contacts of the limestone beds with the enclosing dolomite are usually gradational, the limestone being surrounded by a narrow envelope of partially dolomitized limestone.

Sedimentary structures are abundant in the chert-poor zone, especially in the south where their presence is accentuated by chert. Crinkly algal lamination is almost universally present, while ripple-marks, climbing ripples, interference ripple-marks and ripple cross-lamination are common. A bed of edgewise conglomerate was observed in one locality. Lateral-linked stromatolite domes are common. They range in diameter from 20 centimetres to a metre. These domes are often capped by centimetre-thick layers of carbonaceous shale. Columnar stromatolites have been recorded from one locality (Plate 1F).

Particularly diagnostic of this zone are a class of highly elongated mega-domes. These structures have a short-axis dimension of 3 or 4 metres; their long axis measurement exceeds the dimension of exposures in the dolomite, and is certainly in excess of 10 metres. The structures have an amplitude of approximately 1 metre. They are characterized by rounded crests and v-shaped troughs (Plate 2A). These structures, particularly well-preserved in the southern portion of the area, are usually found in the upper portion of the chert-poor zone, but have been observed in the basal 40 metres of the unit.

E. THE UPPER DOLOMITE AND CHERT ZONE

The upper dolomite and chert zone forms a distinctive unit which can be recognized from Potgietersrus to the vicinity of the Sudwala Caves (Figure 4). The unit has a mean thickness of 407 metres, varying from 300 metres near Vaalhoek to 450 metres in the Selati trough region. Between Vaalhoek and the Sudwala Caves, the base of the Pretoria Group comes to rest upon successively lower portions of the unit, which is finally eliminated south of the Sudwala Caves.

The upper dolomite and chert zone often has a distinct airphoto pattern, being characterized by a series of small cliffs or ledges, separated by rocky slopes. It has a moderately light tone due to the presence of white-bleached chert rubble.

The upper dolomite and chert unit is typified by the light colour of the associated dolomite. The dolomite is fine-grained crystalline, grey to light grey in colour and is often recrystallized to irregular white patches. The contained chert is present in layers, lenses and cross-cutting bodies and, on the basis of field relationships, is thought to be of replacement origin. Chert layers range from 2-metre-thick bars to delicate laminae some fraction of a millimetre thick; on the average, layers are from 1 millimetre to 10 centimetres

thick. On surface, the chert bleaches white, but fresh exposures often indicate a darker colour, ranging from grey to black. In the Pilgrims Rest district, a metre-thick bar of chert developed some 220 metres above the base of the unit was used as a marker in tracing horizons favourable to gold mineralization (Von Dessauer, 1909).

In measured sections through the upper dolomite and chert zone, from 2 to 11 (an average of 6) horizons free or relatively free from chert were encountered. These horizons, generally less than 10 metres thick, were found to be of little value to regional correlation. Some of the chert-free strata are characterized by a slightly darker-coloured dolomite than is usual for the zone as a whole.

A very characteristic alternation of dolomite and chert termed the "bread and butter dolomite" has been traced from north of Pilgrims Rest to Potgietersrus. This unit, an important marker in tracing auriferous horizons in the Pilgrims Rest area (Bell, 1921), is developed 125 metres above the base of the upper dolomite and chert zone. Farther north, it is found 135 to 230 metres above the base of the zone. The bread and butter dolomite consists of chert layers an average of 3 centimetres thick spaced an average of 15 centimetres apart (Plate 2B). The chert often shows a vague columnar structure which suggests the former existence of small columnar stromatolites. The positive-weathering chert layers are, on close examination, seen to consist of an intimate intergrowth of chert and dolomite, presumably indicating the incomplete replacement of dolomite by chert.

On metamorphism, the dolomite develops scattered prisms of amphibole and some mica flakes. At dolomite-chert interfaces, the amphibole may be very well developed in layered tufted masses. Northwest of Potgietersrus, a reaction of dolomite and chert has produced abundant serpentine and lime-rich carbonates. The serpentine often replaces chert, so that delicate sedimentary structures are outlined by serpentine laminae.

Thin beds of black carbonaceous mudstone and shale are found at intervals throughout the column, but are particularly well developed in the Pilgrims Rest area, where they are concentrated in the basal 30 to 40 metres of the unit. The abundance of these "middle" shales, first recorded by Von Dessauer (1909), prompted Zietsman (1964) to separate off this shale-rich portion of the dolomite as a separate unit in the Pilgrims Rest area. Such a subdivision is impossible to implement on a regional scale, since the number and thickness of the argillaceous beds decreases away from Pilgrims Rest. This region is apparently a focal point for the development of clastic sediments. Some of the "middle shales" are in fact fine-grained argillaceous quartzites. In this area, a further distinctive argillaceous horizon termed the "slate marker" (recorded by Von Dessauer, 1909) is encountered some 130 to 140 metres above the base of the unit. The only sedimentary structure of note in the shales was a mud-cracked bedding plane observed in one of the "middle shales".

Mechanical sedimentary structures are commonly seen in the upper dolomite and chert unit and include ripple-marks, interference ripple-marks and climbing ripples. In addition, beds of poorly-preserved edgewise conglomerate are present, as are some oölite beds. Organogenic sedimentary structures are very well developed, algal lamination and stromatolite domes being particularly common. Domes are laterally linked and are generally in the 10 centimetre to 1 metre diameter-range, but some exceptionally large domes with dimensions of the order of 10 metres have been observed. Zietsman's (1964) "beehive chert marker", a distinctive marker in the Pilgrims Rest-Vaalhoek area, consists of laterally-linked domes up to 1 metre in diameter and 2 metres high (Plate 2C). It is developed approximately 175 metres above the base of the upper dolomite and chert zone. Definite columnar stromatolites are extremely poorly preserved, having been recorded in only two localities in the area studied. In these cases, columns 1 or 2 centimetres in diameter and up to 5 centimetres high were noted.

F. THE MIXED ZONE

The mixed zone is characterized by the heterogeneity of its constituent lithologies. In addition to the dolomite and chert alternations which characterize the lower units, significant amounts of limestone and banded iron formation are present in the unit. Where it is not truncated by the base of the Pretoria Group, the mixed zone has a thickness which averages 340 metres.

The mixed zone represents a new cycle of deposition which ensued after the hiatus that terminated the upper dolomite and chert unit. The basal unit of the mixed zone is usually a thin bed (about 1 metre thick) of chert-in-shale breccia. This bed, which has been encountered in most of the measured sections between Vaalhoek and Chuniespoort, conforms to the general description of chert-in-shale breccia given earlier. The sedimentation of the mixed zone was ushered in by the deposition of a significant body of mudstone with a wide lateral extent (Figure 6). The mudstone rests upon the dolomite and chert of the underlying unit or upon the chert-in-shale breccia. On a regional scale, the mudstone has a lenticular geometry, attaining a maximum thickness of nearly 20 metres in the Abel Erasmus Pass region. The mudstone thins to 1 or 2 metres in the Chuniespoort area and to about 10 metres at Vaalhoek. This mudstone marker is black and carbonaceous and in it bedding structures are poorly preserved, having been obliterated by the shearing caused by the intrastratal slip which occurred along this plane. In places, the mudstone shows interbedded lighter-coloured silty layers and poorly-preserved ripple-marks. Iron oxide specks after pyrite are common. In rare instances, needles of metamorphic grunerite were observed in the mudstone.

The mudstone marker is overlain by a succession of dolomites and limestones with subordinate bodies of banded iron formation and minor chert (Figure 6). The dolomites are fine-grained crystalline; they weather chocolate brown or dark grey. On fresh surfaces they vary from black to medium grey in colour. Quartz blebs are virtually ubiquitous, while pyrite euhedra in the dolomite are very common. In some instances the dolomite is banded, centimetre-thick layers of dark grey and grey dolomite being observed. On metamorphism, prisms of amphibole and mica flakes are developed in the dolomite.

The chert present in the mixed zone is usually banded lighter and darker grey on a centimetre-to-millimetre scale. Chert is entirely subordinate in volume, especially in the south where it is all but absent. It is typified by the discontinuous nature of its development, being found in nodules, lenses, cross-cutting bodies and discontinuous layers.

The limestone bodies present in the unit are typified by their lateral discontinuity (Figure 6). On a gross scale, dolomite-limestone contacts are clearly disconformable to bedding. The disconformable relation can often be made out on single outcrops, the limestone-dolomite contact transgressing planes of stratification. Limestone bodies are generally enclosed by an envelope of partially dolomitized limestone. Here, limestone beds are embayed by layers, lenses and cross-cutting bodies of calcareous dolomite (Plate 2D). Numerous instances of partial dolomitization were observed; in one case, stromatolite columns had suffered dolomitization, while the inter-column fill had escaped this process.

The limestone bodies found in the lower 200 metres of the mixed zone tend to be thin (generally less than 15 metres thick) and laterally discontinuous. Figure 6 shows one possible interpretation of the lateral relationships of these bodies of limestone. Near the top of the mixed zone, a thick and continuous body of limestone can be traced from the Abel Erasmus Pass to the Potgietersrus region. This body commonly measures up to 100 metres in thickness.

The limestones described above are considered to have a primary origin. The most compelling field evidence for their primary nature lies in the degree of preservation of sedimentary structures. In this rock-type, delicate algal stromatolites, öölites, ripple-marks, cross-beds and beds of edgewise conglomerate are exceptionally well-preserved, especially in the south where the effects of Bushveld metamorphism are negligible. In the dolomites, sedimentary structures are, in most cases, obliterated and, where preserved, are certainly nowhere as clear as in the limestone. In particular, the main body of limestone beneath the banded ironstone in the Abel Erasmus Pass area (Figure 6) is characterized by a remarkably well-preserved suite of shallow-water sedimentary structures. The same stratigraphic horizon a few miles to the south, here composed of dolomite, is typified by the almost total absence of sedimentary structures. A primary origin for the limestones is thus favoured, the well-preserved structures in the limestone having been obliterated during the dolomitization process. The inverse reasoning would be hard to apply; the apparently structureless dolomite would, on dedolomitization, need to be converted into a limestone showing excellent preservation of structures.

Where unaltered, the limestone is generally a very finely crystalline rock, sooty and pitch black or dark grey in colour. On outcrop, the limestone weathers a dark to light grey colour. Limestone outcrops are typified by their fluted weathering surfaces. Blebs of quartz, veinlets of calcite and pyrite euhedra were observed in the limestone. The limestones described above are often recrystallized, especially under the influence of Bushveld metamorphism. Recrystallized limestones are medium-grained and are lighter coloured. Where partially recrystallized, they show a white-mottled appearance due to the presence of clots of white crystalline calcite. Where metamorphosed, they often carry flakes of metamorphic mica.

The limestones are obviously more prone to recrystallization than dolomite. In a succession of interbedded dolomite and limestone, the latter is often recrystallized to a greater or lesser extent while the former is apparently unaffected. In comparison with dolomite, the limestone is also structurally incompetent. The centimetre-thick beds of calcareous-carbonaceous shale developed in dolomites of the mixed zone often retain their original characteristics. Those present in the limestone are often strongly deformed. In the first instance, they become intensely folded and show patterns reminiscent of ptygmatic folding (Plate 2E). In more extreme cases, the shale beds become disrupted and are present as angular slabs and plates of shale in a limestone devoid of any of its original bedding structures.

In the mixed zone, sedimentary structures are apparently much less common than in the preceding units. This fact does not necessarily reflect on the primary depositional environment, but is rather a reflection of the paucity of chert (which weathers to accentuate structures) and the metamorphic recrystallization of the carbonates. Structures are, however, by no means absent, and are particularly well seen in the Abel Erasmus Pass region. Mechanical sedimentary structures include ripple-marks, ripple cross-lamination, cross-bedding and edgewise conglomerate. In places, the latter form metre-thick beds containing imbricated slabs of carbonate up to 20 by 5 centimetres in size (Plate 3A). Oölites are present, occasionally in cross-bedded layers interbedded with the conglomerates described above. They are also found in the voids between stromatolite columns. Organo-sedimentary structures include algal lamination and various types of stromatolites. Lateral-linked domes have been observed. Some have diameters up to 3 or 4 metres and an amplitude of about 50 centimetres. More commonly seen are 10 centimetre-scale linked stromatolite domes. Small columnar stromatolites are well-preserved in limestones of the basal 50 metres of the mixed zone in the area between Abel Erasmus Pass and Vaalhoek. The columns are 2 to 5 centimetres high and 1 or 2 centimetres in diameter. They are not linked laterally, being of the stacked hemispheroidal type (Plate 3B). These small columns have been observed to form the minor structure for some of the larger metre-scale domes.

In addition to the above structures, a peculiar contorted structure, possibly algal in origin, was observed in the mixed zone. This structure (Plate 3C), despite its enigmatic origin, is a useful correlatory indicator, having been found in the mixed zone at Zeerust, some 500 kilometres away.

At a level ranging from about 10 to 70 metres above the base of the mixed zone, thin beds (less than 1 metre thick) of a very characteristic shaly rock are present (Figure 6). This sediment consists of a green-grey shaly matrix in which angular, grey or white, millimetre-sized fragments are present. The rock-type has a wide distribution in the mixed zone, having been encountered in nearly all the measured profiles between Vaalhoek and Potgietersrus. Under the microscope, this rock, which resembles a tuff, is seen to be composed of small shards of altered volcanic glass with some quartz, albite and microcline grains set in very fine-grained sericite-chert groundmass.

Within the mixed zone, at least two horizons of banded ironstone are developed before the onset of the Penge Formation. The first occurrence is in the dolomite a few metres above the mudstone marker. This bed, about 1 metre thick, has a lateral extent measurable in hundreds of metres only. The second horizon, some 30 metres thick, has been traced from north of Penge to Chuniespoort (Figure 6). In both of these occurrences, a banded chert-sideritic dolomite assemblage carries layers and lenses of grunerite rock and magnetite (Plate 3D). The sideritic carbonates are striking rocks, weathering with vivid mustard or russet-coloured surfaces. The grunerite is present in layers of disoriented acicular crystals, often carrying scattered magnetite grains. On weathering, the grunerite is reduced to a

yellow powder which is often subsequently silicified to produce a hard, yellow cherty rock in which the pattern of the original needles is seen. The magnetite, very often hematized, is present in layers, laminae and as scattered small crystals in the grunerite rock.

The contact between the Malmani dolomite and the Penge Formation is a gradational one. The style of gradation varies across the area. In the south, around Penge, the main body of limestone in the mixed zone becomes dolomitized along its upper contact; this dolomitic rock grades rapidly to a banded sideritic dolomite-chert-grunerite-magnetite horizon, which, in this area, is taken to represent the base of the Penge Formation. This body of ferruginous sediment is succeeded by a thickness of carbonaceous mudstone which is, in turn, overlain by the principal banded ironstone in which the mineable fibres of grunerite asbestos are developed.

From the Mhlapitsi River area to Chuniespoort, the principal banded ironstone grades down to a limestone with numerous beds of calcareous and carbonaceous mudstone, some of these argillaceous sediments carrying centimetre-thick chert layers. This assemblage grades downwards to the principal limestone of the mixed zone.

The changes in the nature of the Malmani Dolomite-Penge Formation contact are best explained by the northward pinching out of the basal sideritic dolomite-chert-grunerite-magnetite rock of the Penge area and by the thinning of the overlying mudstone unit and a concomitant facies change to a shale-limestone assemblage. A thinning of the mudstone portion of the Penge Formation to the north can reasonably be expected, all the major clastic units in the Malmani Dolomite thinning in this direction.

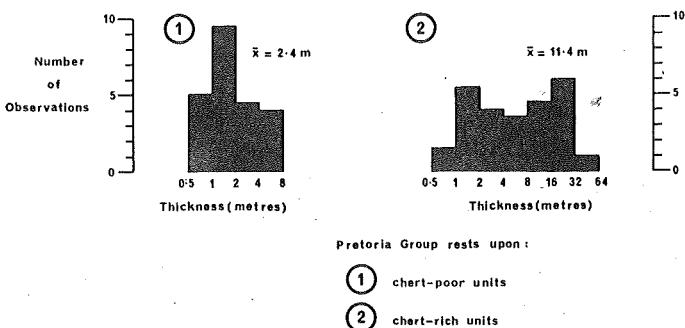
THE RELATION OF THE PRETORIA GROUP TO THE OLIFANTS RIVER GROUP

As early as 1910, Hall recognized that the "Bevets Conglomerate", which caps the dolomite in the Pilgrims Rest area, represented a "slight but extensive unconformity between the Pretoria Series and the Dolomite" (Hall, 1910, p. 99). Schwellnus and others (1962) mentioned the unconformable relationship between the Pretoria Group and the Olifants River Group in the area southeast of Penge. Zietsman (1964) showed that the "Bevets Conglomerate" and "Giant Chert" lie unconformably on the dolomite stratigraphy, eliminating various well-defined markers when traced southward in the Pilgrims Rest-Sabie area. The documentation of the pre-Pretoria Group unconformity in the eastern Transvaal is thus by no means new, but the panel-diagram in Figure 4 shows the relationship over a larger area than has heretofore been the case. In this diagram, the base of the Pretoria Group is shown to rest upon the Duitschland Formation (in the Potgietersrus area), the Penge Formation (in its type area) and, in turn, upon each of the four major units of the Malmani Dolomite.

Rapid lateral thickness changes typify the "Bevets Conglomerate"- "Giant Chert" unit. Zietsman (1964), noting thickness changes in the 5 to 50 feet range, concluded that "the variation in thickness in the Pilgrims Rest area is probably due to a local depression in the floor of deposition". In the Delmas area, a study of the thickness of the correlative unit (Button, 1968) led to the conclusion that thicknesses were greatest where the Malmani Dolomite had suffered maximum uplift and erosion in pre-Pretoria times. Areas subjected to greater uplift yielded larger volumes of insoluble chert residue. Though both of these factors certainly contribute to the control of the breccia thickness, a third and more fundamental control was discovered during the present investigation. It was found that, where the Pretoria Group rests upon one of the chert-poor zones, the thickness of basal clastic unit is minimal (Figure 7, histogram I) and in no case exceeded 8 metres. Conversely, where it rests upon one of the chert-bearing units, the chert-breccia varies in thickness up to a maximum of 56 metres. The mean thickness of the basal unit of the Pretoria Group is 2.4 metres in the first case, in the second it is 11.4 metres. It is apparent that the fundamental control of thickness is the abundance of chert in the dolomite which immediately underlies the Pretoria Group.

THICKNESS HISTOGRAMS - COARSE CLASTIC UNIT AT BASE OF PRETORIA GROUP

FIG.7



CYCCLICAL SEDIMENTATION IN THE MALMANI DOLOMITE

In the Malmani Dolomite, the vertical pattern of lithological variation may be shown as a series of cycles which are reflected by the systematic repetition of various sediment-types and sediment assemblages. A noticeable feature of the succession in the dolomite is the tendency of a sediment or sedimentary suite to grade into a particular sedimentary assemblage. Thus, significant bodies of quartzite were observed to grade into an assemblage composed of dark dolomite, poor in chert and with abundant beds of mudstone and quartzite. The principal banded ironstone occurrences grade upward and downward into a suite of dark dolomites with beds of limestone, mudstone, banded ironstone and minor chert. These sediment associations are graphically portrayed in Figure 8, a sediment-association chart constructed for the Malmani Dolomite. As a general rule, any lithological assemblage portrayed on this chart grades along a tie-line to one of the neighbouring lithological suites. Thus, for example, in no case was a gradational contact between the banded ironstone-mudstone assemblage and the light coloured dolomite and chert assemblage noted.

Certain qualitative changes accompany the lithological gradations shown in Figure 8. The carbonates tend to become richer in Fe, Mn and Ca and poorer in Mg from base to top of the chart. The percentage of interbedded clastics tends to increase in sympathy with Fe-Mn-Ca, while the proportion of chert interbedded in the dolomite increases with the Mg content of the dolomite. The culmination of the Malmani Dolomite in the banded ironstone-mudstone association of the Penge Formation is thus a consequence of this increase of Fe and clastics in a sedimentary cycle.

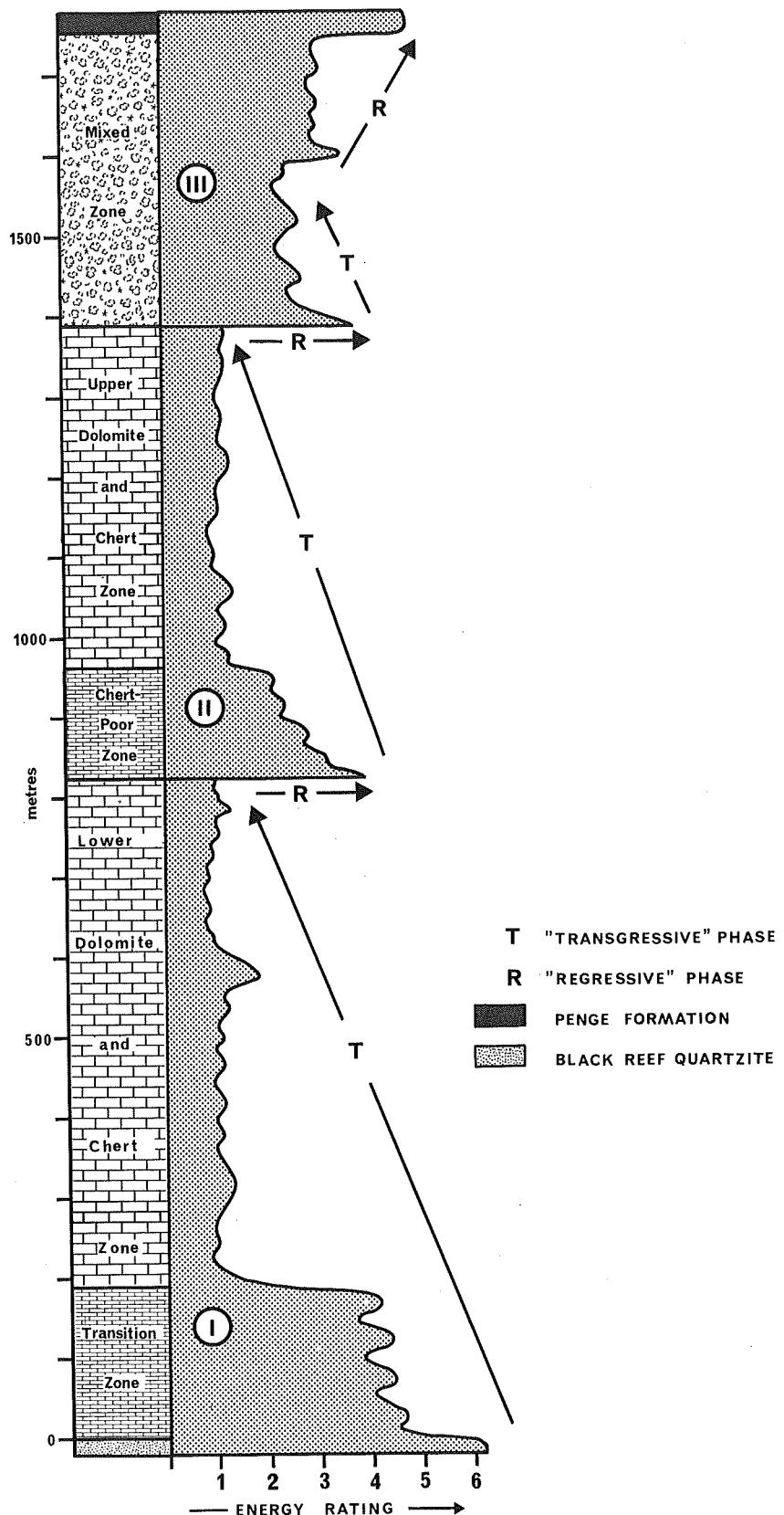
In the chart of Figure 8, the sediment associations have been ranked on a qualitative "energy-scale", which takes account primarily of the abundance and coarseness of clastic sediments and is presumably a measure of the stability of the crustal block on which deposition took place. (It is assumed that, if any differential crustal movements occurred in the vicinity of the depository, they would be reflected by the introduction of clastic sediments into that depository).

The qualitative energy-rankings which are deduced from the association diagram of Figure 8 have been used to construct a model of the cyclical deposition for the dolomite stratigraphy in the Selati trough region, where the formation is most fully developed. This diagram was constructed by assigning the qualitative numerical values to sediment associations

MALMANI DOLOMITE - CYCLICAL SEDIMENTATION

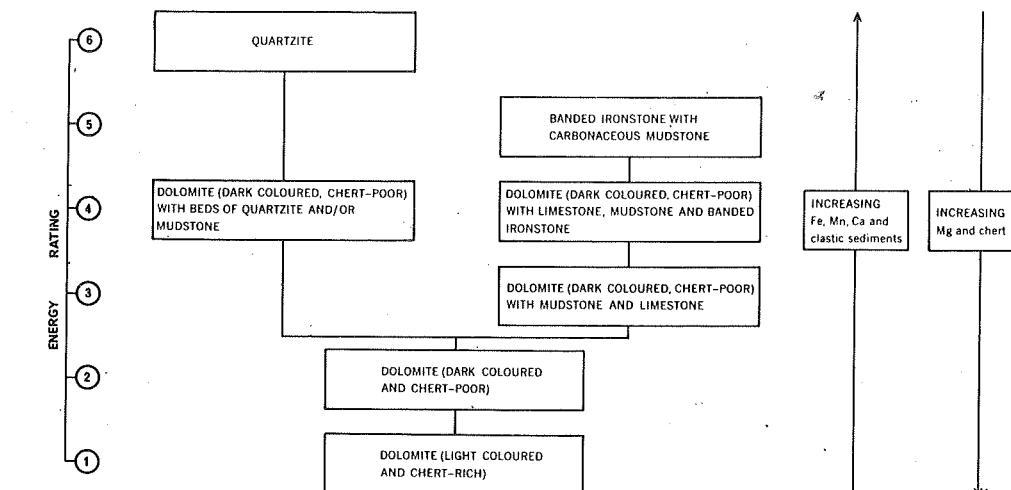
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FIG. 9



SEDIMENT ASSOCIATION CHART-MALMANI DOLOMITE

FIG. 8



developed through the stratigraphy. The resulting cyclical model is shown in Figure 9. From Figure 9, it is evident that the dolomite stratigraphy is divisible into three first-order cycles upon which numerous second-order cycles are superimposed. The cycles commence with a suite rich in clastics (abundant quartzite and mudstone in I, mudstone with rare quartzite in II, mudstone alone in III) and grade upwards to "low-energy" assemblages. Such gradations are usually ascribed to a "transgression", in which it is envisaged that facies-belts migrated landward due to a relative downward movement of the basin margin.

The tops of cycles I and II are sharply truncated, the planes of truncation being covered, in most places, by a bed of chert-in-shale breccia. A sharply truncated cycle in which "high-energy" coarse clastics rest directly upon "low energy" sediments suggests an uplift of the basin margin with respect to the depository and a resultant shift of facies belts basinward. In extreme cases, the erosional facies-belt surrounding a basin may migrate onto sediments deposited in the basin, resulting in an intraformational erosional hiatus. It is suggested that the sharp breaks in sedimentation reflect such disconformities and that the layers of breccia represent the chert detritus left on a surface of disconformity. These thin bodies of intraformational breccia are considered to be entirely analogous to the thick breccias found along the pre-Pretoria unconformity.

COMPARISON OF STRATIGRAPHY WITH OTHER AREAS

The only studies of dolomite stratigraphy in the Transvaal which are applicable to the present investigation are those of Young (1933), Toens (1966) and Eriksson (1971). The above studies were made on dolomite cores drilled from the Potchefstroom Synclinorium, a subsidiary structural basin developed to the south of the principal Transvaal basin. The most comprehensive account of dolomite stratigraphy is that of Eriksson (1971), who presents a composite column for this area. Eriksson has subdivided the dolomite into ten units largely on the basis of sedimentary structures and carbonate textures. In the diagram shown in Figure 10, Eriksson's composite column has been modified to conform to the type of gross-lithological subdivision employed in the eastern Transvaal.

MALMANI DOLOMITE - REGIONAL CORRELATION

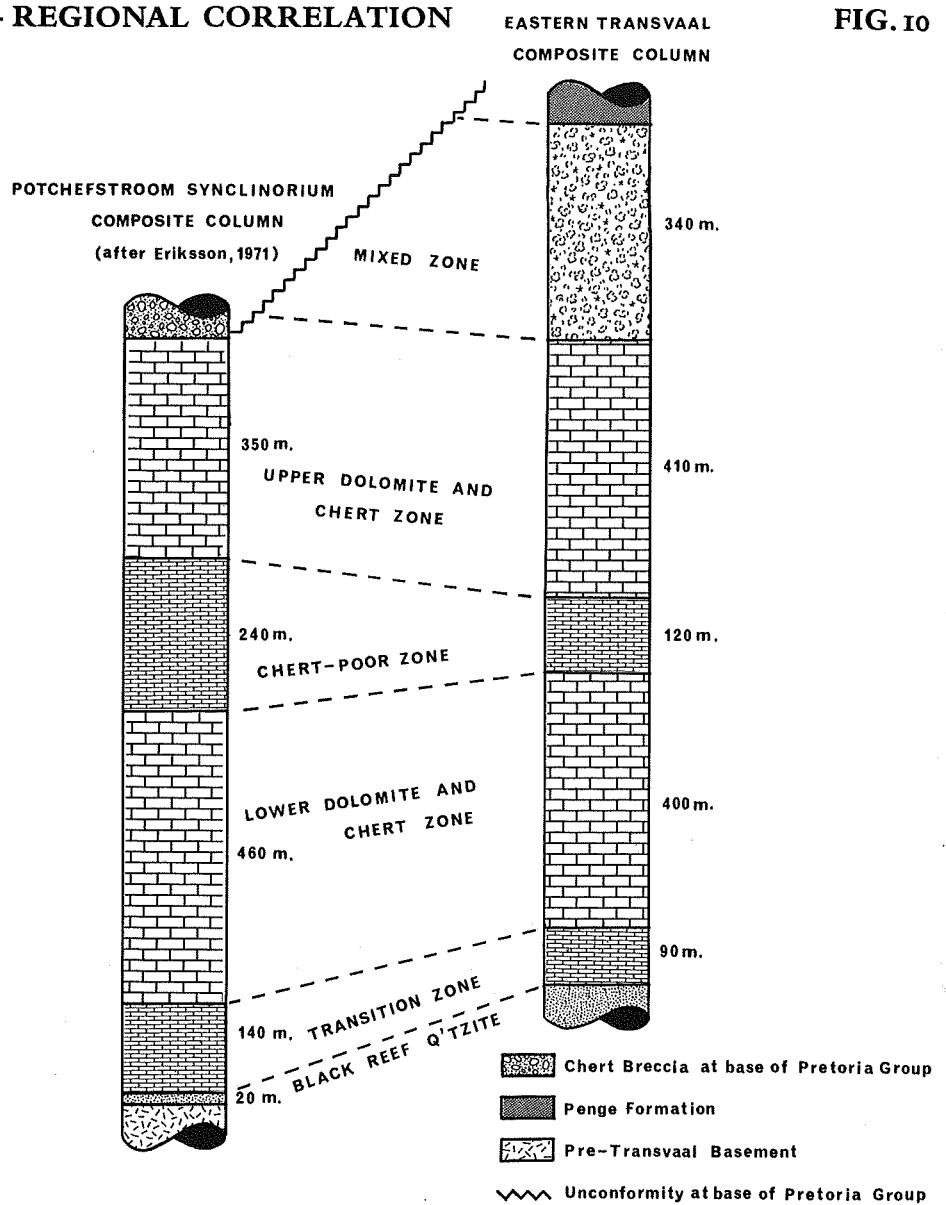


FIG. 10

Regional correlation between the two areas can be confidently performed. The four gross lithological units developed in the Potchefstroom area correspond to the four lowest subdivisions established in the eastern Transvaal. The mixed zone of the Malmani Dolomite and the Penge Formation were, in all probability, deposited in the Potchefstroom area, but were bevelled off during the erosional period which immediately preceded Pretoria Group deposition.

The transition zone (0-200 metres thick) has a counterpart in the Potchefstroom area. The most striking difference between the two areas lies in the proportion of clastic sediments in the dark chert-free dolomites of this zone. Quartzites and mudstones are developed through as much as 200 metres in the eastern Transvaal; mudstones are found in the Potchefstroom area, but are encountered only immediately above the Black Reef Quartzite (Eriksson, 1971).

The lower dolomite and chert zone is similar in the two areas, the 460 metre thickness of the Potchefstroom area falling comfortably within the 200 to 650 metre thickness-range for the unit in the east. The abundance of chert and the light colour of the dolomite are common in the two areas, as are the abundance of oölites and domical stromatolites.

The middle chert-poor zone is almost twice as thick in the Potchefstroom area as in the eastern Transvaal. This zone is characterized by a greater proportion of clastic sediments in the east, where the Blyde River Quartzite and its accompanying shales are found. The sharp break in sedimentation at the base of this zone (marked by the chert-in-shale breccia) was not recorded from the Potchefstroom area, where the contact is evidently gradational. The thin beds of limestone developed in the vicinity of the basin axis in the eastern Transvaal have no counterpart in the Potchefstroom area.

The upper dolomite and chert unit, 350 metres thick in the Potchefstroom area, is similar in most respects to the equivalent zone in the east, where thicknesses range from 300 to 500 metres. An exceptional feature of the unit in the eastern Transvaal is the abundance of mudstone beds developed near the base of the unit.

In summary, a broad correlation of dolomite stratigraphy in the two areas may be confidently drawn. The eastern Transvaal is characterized by the greater proportion of clastic sediments interbedded in the carbonates, while in the Potchefstroom area, the dark chert-poor units are considerably thicker than their counterparts in the east. The prominent unconformity recorded at the base of the chert-poor zone in the eastern Transvaal has no counterpart in the Potchefstroom area. It would appear that the eastern Transvaal, both by the high proportion of clastics and by the prominence of intraformational unconformities, represents a more proximal facies of dolomite deposition than in the Potchefstroom Synclinorium.

The limestone bodies described in this paper have not been previously documented in the Transvaal province. They are, however, very similar to the limestones developed in the correlative Campbell Rand Dolomite of the northwestern Cape. In this area, lenses of limestone start appearing at a stratigraphic level which is estimated to be some 1200 metres from the top of the dolomite (Toens, 1966). These lenses increase in number and thickness upwards, and culminate in a 120 metre thick body of limestone which is found a small distance below the overlying banded ironstones. The limestone lenses are enclosed by an envelope of low-grade limestone which is, in turn, enclosed by a white, "coarse-grained" dolomite.

The limestones described here occupy a similar stratigraphic position (with respect to the banded ironstones) and show cross-cutting dolomite-limestone contacts which are identical to those described from the northern Cape. The lenses of limestone are evidently developed through a greater thickness in the Cape (1200 metres) in comparison to the Transvaal (880 metres). The thickness of the principal limestone horizon in the two areas is essentially the same. A significant difference between the two areas is the fact that the northern Cape deposits are enclosed in a white "coarse-grained" dolomite, while those of the Transvaal are found in a fine, dark coloured dolomite. Toens mentions remnants of dark, fine-grained dolomite in the white dolomite and is of the opinion that the latter was formed by the alteration of a primary dark dolomite.

SUMMARY OF CONCLUSIONS

In the eastern and northeastern Transvaal, the Malmani Dolomite varies in thickness between the limits of 100 and 1700 metres. The formation attains its maximum thickness in the Selati trough, an east-northeasterly-trending tectonic feature developed along the trace of the Murchison schist belt. It is significant that both the Wolkberg Group and the Black Reef Quartzite reach their thickest development along this trough. From the Selati trough, thicknesses decrease to 1400 metres in the Potgietersrus area and to 100 metres in the south, around Badplaas. The southerly thinning of the Malmani Dolomite is due in part to a gradual decrease in the thickness of some of its constituent units, but the effect of the pre-Pretoria Group unconformity (which truncates successively lower units in a southerly direction) is more important. The southeastern flank of the Transvaal basin has, in Dolomite and post-Dolomite times, been tectonically relatively positive.

On the basis of dolomite colour and the abundance of interbedded chert, mudstone, quartzite, limestone and banded ironstone, five regionally-significant stratigraphic units were recognized in the Malmani Dolomite. The lower, middle and uppermost units are characterized by dark-coloured dolomite relatively free of chert; the two intervening units are of light-coloured dolomite with abundant chert. The basal unit (the transition zone) carries abundant quartzite and mudstone, the middle unit carries some mudstone, quartzite and limestone, while the upper unit carries mudstone with lenses of limestone and some banded ferruginous sediments.

The cyclical pattern of sedimentation in the Malmani Dolomite is striking, being recognized primarily by the percentage of clastic sediments (quartzite and mudstone) interbedded in the carbonates. Three first-order cycles are developed which are separated by two disconformities. The disconformities are usually capped by a chert-in-shale breccia, which is overlain by a phase rich in clastic sediments. A pattern of iron enrichment upwards through the cycles culminated in the deposition of the banded ironstones of the Penge Formation.

The regional distribution pattern of the subdivisions of the Olifants River Group is controlled primarily by the pre-Pretoria unconformity. When traced southwards from the basin-axis, the Pretoria Group rests, in turn, upon the Duitschland Formation, upon the Penge Formation and on the four principal units of the Malmani Dolomite. The thickness of the chert breccia and conglomerate which caps this unconformity is, not unexpectedly, primarily controlled by the abundance of chert in the unit upon which it rests.

Portions of the stratigraphy of the Malmani Dolomite in the eastern Transvaal may be confidently correlated with the same units in the Potchefstroom area. The four lowest units of the eastern Transvaal are present in the latter area, but the mixed zone and higher units were eliminated, in the Potchefstroom area, by pre-Pretoria Group erosion. Significant differences in detail are noted between the two areas. In particular, the dark, chert-poor units are thinner and contain more abundant quartzite and shale in the eastern Transvaal. In addition, one of the distinct breaks in sedimentation noted in the east is apparently absent in the Potchefstroom area. The abundance of clastic sediments, the thinner development of the dark dolomite zones and the presence of intraformational disconformities all point to the eastern Transvaal being nearer to the margin of the dolomite depositional basin than the Potchefstroom area.

The economically exploited limestone deposits of the northwestern Cape have analogies in the northeastern Transvaal. In the middle chert-poor unit and, more importantly, in the mixed zone, beds and lenses of limestone are found. The lenses become thicker and laterally more persistent upwards. They culminate in a zone some 100 metres thick (composed predominantly of limestone) developed just below the banded ironstones of the Penge Formation. This limestone horizon presents an excellent exploration target for companies interested in outlining enormous tonnages of primary limestone.

The limestones are usually surrounded by an envelope of partially dolomitized limestone. Dolomite-limestone contacts cut sharply across the bedding on a local and a regional

scale. Delicate sedimentary structures are preserved in the limestone. For these reasons, the limestone is considered to represent the primary carbonate precipitated in the Proterozoic platform-sea which covered parts of the southern African subcontinent some 2000 million years ago. Subsequent dolomitization has all but destroyed this primary carbonate, the limestone being preserved in laterally discontinuous lenses in a restricted portion of the stratigraphy.

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List of References

- Bell, H.C.F., 1921, Some Notes on the Pilgrims Rest Gold Fields : Jour. Chem. Met. Min. Soc. S. Afr., Vol. 22, p. 79-85.
- Button, A., 1969, Stratigraphic Analysis of the Transvaal Sequence in the Irene-Delmas-Devon Area, Transvaal : Econ. Geol. Res. Unit, Inf. Circ. No. 51, 12 pp.
- Button, A., 1972, The Depositional History of the Wolkberg Proto-Basin, Transvaal : Econ. Geol. Res. Unit, Inf. Circ. No. 71, 18 pp.
- Davies, R.D., Allsopp, H.L., Erlank, A.J. and Manton, W.I., 1969, Sr-Isotopic Studies on Various Layered Mafic Intrusives in Southern Africa : Spec. Pub. No. 1, Geol. Soc. S. Afr., p. 576-593.
- Dreyer, C.J.B., 1967, The Geology of the Bewaarkloof Area, Pietersburg Asbestos Field : Unpub. M.Sc. Thesis, Univ. Witwatersrand, 80 pp.
- Du Toit, A.L., 1945, The Origin of the Amphibole Asbestos Deposits of South Africa : Trans. geol. Soc. S. Afr., Vol. 48, p. 161-206.
- Eriksson, K.A., 1971, A Basin Analysis of the Transvaal Sequence in the Potchefstroom Synclinorium, Transvaal and Orange Free State : Unpub. M.Sc. Thesis, Univ. Witwatersrand, 79 pp.

- Hall, A.L., 1910, The Geology of the Pilgrims Rest Gold Mining District : Mem. 5, Transvaal Mines Dept., Pretoria, 158 pp.
- Hall, A.L.; 1912, The Geology of the Murchison Range and District : Mem. 6, Geol. Surv. S. Afr., 186 pp.
- Hall, A.L., 1914, The Geology of the Haenertsburg Goldfield and Surrounding Country : An Explanation of Sheet 13 (Olifants River), Geol. Surv. S. Afr., Pretoria, 62 pp.
- Hall, A.L., 1918, The Geology of the Country Round Belfast : An Explanation of Sheet 16 (Belfast), Geol. Surv. S. Afr., Pretoria, 56 pp.
- Hall, A.L., 1930, Asbestos in the Union of South Africa : Mem. 12, Geol. Surv. S. Afr., Pretoria, 324 pp.
- Kynaston, H., Mellor, E.T. and Hall, A.L., 1911, The Geology of the Country Round Potgietersrust : An Explanation of Sheet 7 (Potgietersrust), Geol. Surv. S. Afr., 62 pp.
- Nicol Brown, 1896, The Succession of the Rocks in the Pilgrims' Rest District : Trans. geol. Soc. S. Afr., Vol. 2, p. 3-4.
- Reinecke, L. and Stein, W.G.A., 1929, Ore Bodies of the Pilgrims Rest Goldfield : Trans. geol. Soc. S. Afr., Vol. 32, p. 65-88.
- Schwellnus, J.S.I., Engelbrecht, L.N.J., Coertze, F.J., Russel, H.D., Malherbe, S.J., van Rooyen, D.P. and Cooke, R., 1962, The Geology of the Olifants River Area, Transvaal : An Explanation of Sheets 2429B (Chuniespoort) and 2430A (Wolkberg), Geol. Surv., S. Afr., Pretoria, 84 pp.
- Thord-Gray, I., 1905, Notes on the Geology of the Lydenburg Gold Fields : Trans. geol. Soc. S. Afr., Vol. 8, p. 66-78.
- Toens, P.D., 1966, Precambrian Dolomite and Limestone of the Northern Cape Province : Mem. 57, Geol. Surv. S. Afr., Pretoria, 109 pp.
- Van Niekerk, C.B. and Burger, A.J., 1964, The Age of the Ventersdorp System : Annals geol. Surv. S. Afr., 3, p. 75-86.
- Vermaas, F.H.S., 1952, The Amphibole Asbestos of South Africa : Trans. geol. Soc. S. Afr., Vol. 55, p. 199-229.
- Visser, D.J.L. (Compiler), 1956, The Geology of the Barberton Area : Spec. Pub. 15, Geol. Surv. S. Afr., Pretoria, 253 pp.
- Visser, H.N. and Verwoerd, W.J. (Compilers), 1960, The Geology of the Country North of Nelspruit : An Explanation of Sheet 22 (Nelspruit), Geol. Surv. S. Afr., Pretoria, 128 pp.
- Von Dessauer, A., 1909, Some Shales in and Observations on, the Dolomites of Pilgrims Rest : Trans. geol. Soc. S. Afr., Vol. 12, p. 78-81.
- Wilson-Moore, C., 1896, Some Observations of the Geology of the Sabie Valley : Trans. geol. Soc. S. Afr., Vol. 2, p. 131-140.
- Wybergh, W.J., 1925, The Economic Geology of Sabie and Pilgrims Rest : Mem. 23, Geol. Surv. S. Afr., Pretoria, 124 pp.
- Young, R.B., 1933, Conditions of Deposition of the Dolomite Series : Trans. geol. Soc. S. Afr., Vol. 36, p. 121-135.

Zietsman, A.L., 1964, The Geology of the Sabie-Pilgrim's Rest Goldfield : Unpub. M.Sc. Thesis, Univ. Orange Free State, 84 pp.

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Key to Figures

- Figure 1 : Map showing locality of area studied and the regional geology.
- Figure 2 : Schematic diagram showing the stratigraphic relationships of the Transvaal Supergroup in the eastern and northeastern Transvaal.
- Figure 3 : An isopach map constructed for the Malmani Dolomite in the eastern and northeastern Transvaal.
- Figure 4 : A 'round-the-outcrop' panel-diagram showing the stratigraphy and stratigraphic relationships of the Malmani Dolomite.
- Figure 5 : A panel-diagram showing the stratigraphic relationships within the chert-poor zone of the Malmani Dolomite.
- Figure 6 : A panel-diagram showing the internal stratigraphy of the mixed zone and of the Penge Formation.
- Figure 7 : Histograms showing the thickness variation of the basal coarse-clastic unit of the Pretoria Group.
- Figure 8 : A rock-association chart for the Malmani Dolomite.
- Figure 9 : Sedimentary cycles in the Malmani Dolomite.
- Figure 10 : The regional correlation of the stratigraphic units within the Malmani Dolomite.

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Key to Plates

- Plate 1 A : A laminated rock showing dolomite-chert contacts cutting across bedding planes, lower dolomite and chert zone, Badplaas area.
- B : Elongate slabs of chert (outlined by chalk) in a block of carbonaceous shale, lower dolomite and chert unit, Sabie area.
- C : Ripple marks and climbing ripples in dolomite, lower dolomite and chert unit, Badplaas area.
- D : Interference ripple marks in chert, lower dolomite and chert unit, Badplaas area.

E : Lenticular layers of chert (light coloured) in dolomite (darker coloured), chert-poor zone, Vaalhoek area.

F : Columnar stromatolites showing both linked and unlinked habits, base of chert-poor zone, Sabie area.

Plate 2 A : A cross-sectional view of an elongate mega-dome, chert-poor unit, Sabie-Pilgrims Rest area. Bedding planes are accentuated with white ink.

B : An outcrop of "bread and butter" dolomite, upper dolomite and chert zone, Morgendal, south of Haenertsburg.

C : Zietsman's "beehive chert marker", a distinctive stromatolite in the upper dolomite and chert zone, Vaalhoek area. For scale, length of Jacob staff is 1.9 metres.

D : An outcrop of partially dolomitized limestone, mixed zone, Abel Erasmus Pass area. The limestone (negative-weathering) is present in remnant layers and lenses, having been largely replaced by a calcareous dolomite.

E : Highly deformed shale beds in limestone, mixed zone, Ashmoles Dale, south of Haenertsburg.

Plate 3 A : A block of edgewise conglomerate in limestone, mixed zone, Abel Erasmus Pass area.

B : Small columnar stromatolites in limestone, mixed zone, Abel Erasmus Pass area.

C : "Contorted" structure in dolomite of the mixed zone, Abel Erasmus Pass area.

D : An outcrop of a banded sideritic dolomite-chert-amphibole needle rock (D marks sideritic dolomite, C marks chert and ANR marks layers composed of fine grunerite needles). Outcrop photographed from the mixed zone, south of Haenertsburg.

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APPENDIX I

Thickness Statistics - Malmani Dolomite

<u>Stratigraphic Unit</u>	<u>Number of Measurements</u>	<u>Mean Thickness (m)</u>	<u>Standard Deviation in Thickness (m)</u>
Mixed Zone	11	339	62
Upper Dolomite and Chert Zone	11	407	69
Middle Chert-poor Zone	24	123	19
Lower Dolomite and Chert Zone	16	401	178
Lower Chert-poor Zone	6	80	21
Transition Zone	11	88	60

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APPENDIX - DIAGRAM I

COMPOSITE STRATIGRAPHIC COLUMNS FOR THE MALMANI DOLOMITE IN THE EASTERN AND NORTHEASTERN TRANSVAAL

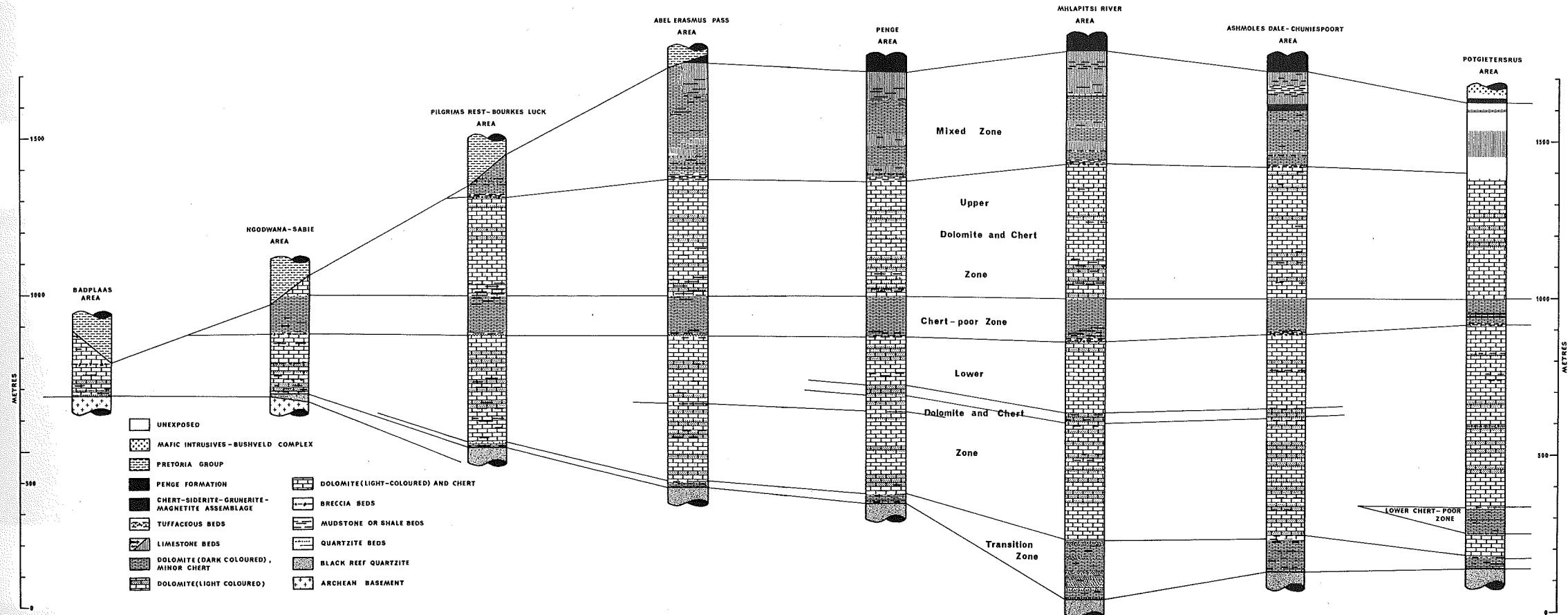


PLATE 1

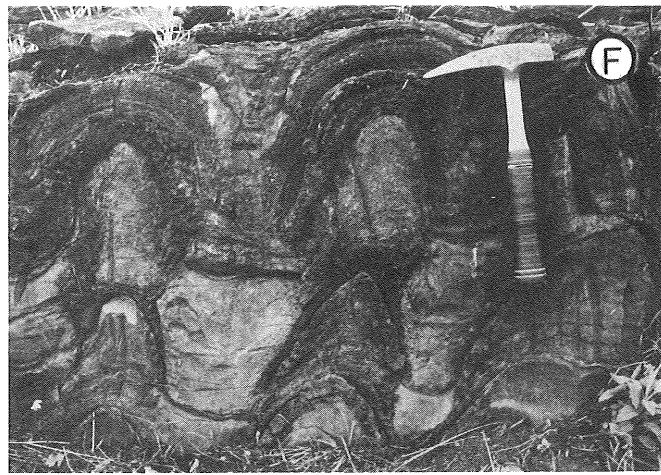
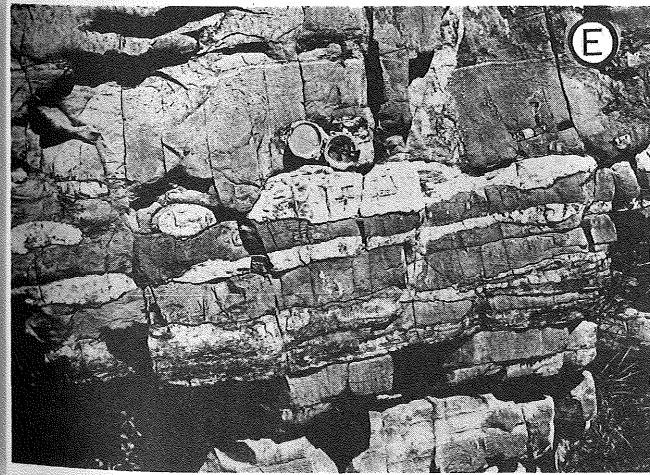
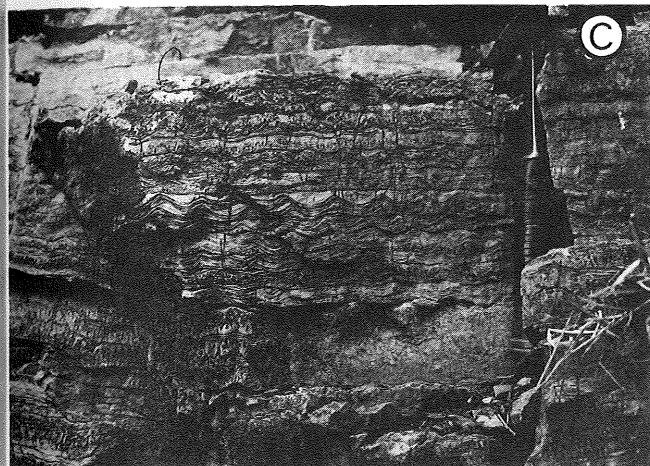
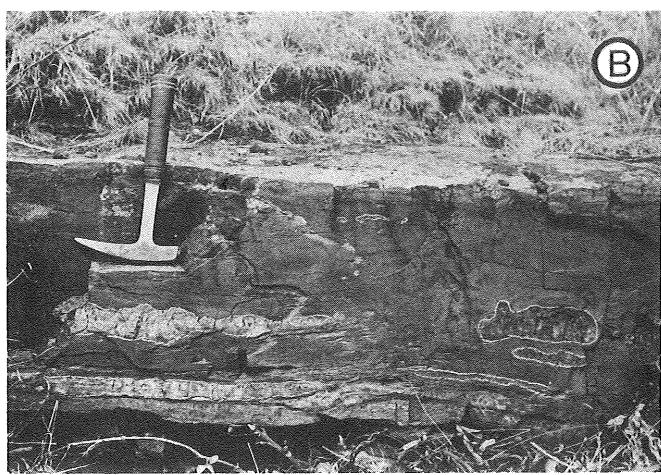
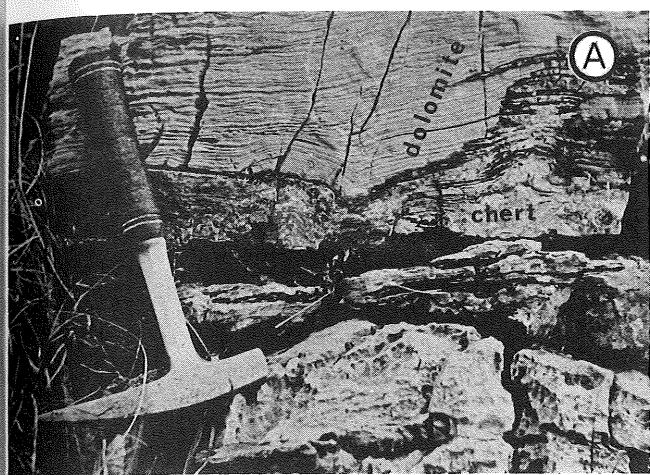


PLATE 2

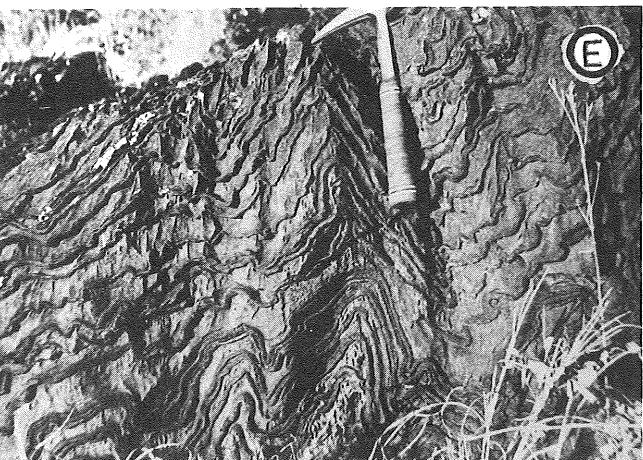
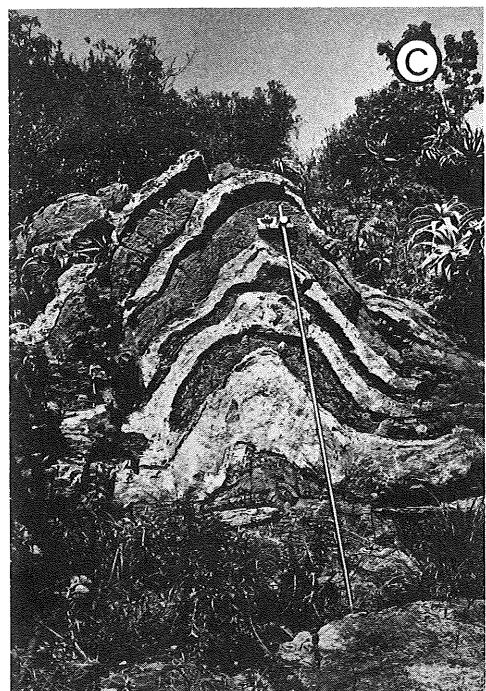
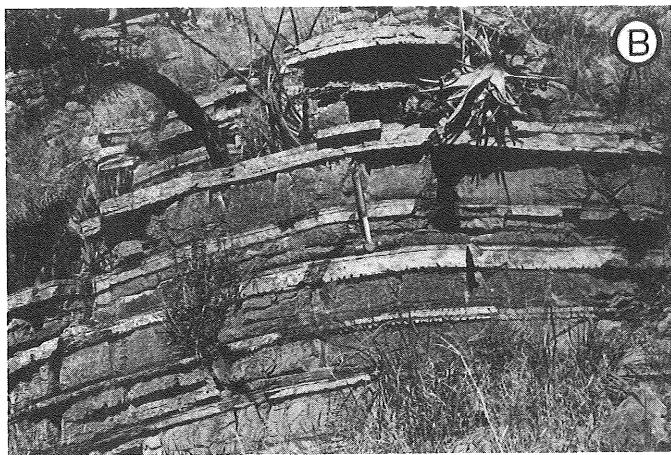
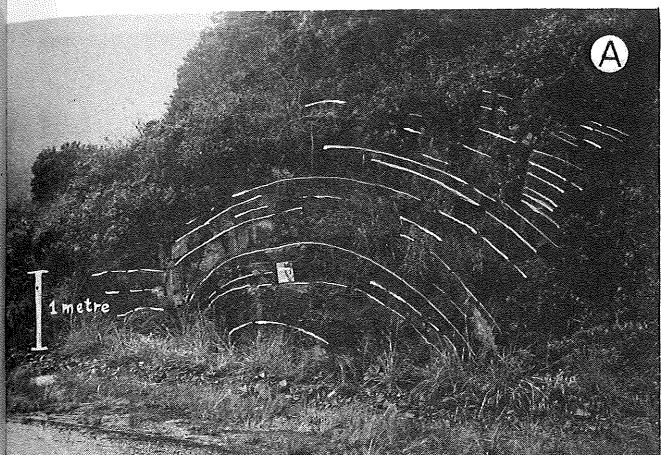


PLATE 3

