FLUVIAL FACIES, VERTEBRATE TAPHONOMY AND PALAEOSOLS OF THE TEEKLOOF FORMATION (PERMIAN) NEAR BEAUFORT WEST, CAPE PROVINCE, SOUTH AFRICA

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I, ROGER MALCOLM HARRIS SMITH, hereby declare that this thesis is my own original work, that all assistance and sources of information have been acknowledged and that this work has not been presented to any other university for the purpose of a higher degree.

Signed by candidate

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FRONTISPIECE In situ *Pristerodon* skull, Karoo National Park, Beaufort West.

ABSTRACT

The main Karoo Basin of South Africa contains a relatively continuous sequence of continental deposits that accumulated over a 100 million year period from Permo-Carboniferous (280 Ma) to early Jurassic (180 Ma). In the southwestern region of the basin the Karoo succession is approximately 4 000 m thick, the upper half of which consists of vertebrate fossil-bearing fluvial rocks of the Beaufort Group.

This study deals with Lower Beaufort (Adelaide Subgroup) strata belonging to the Teekloof Formation which are exposed in the east-west trending erosional escarpment between the towns of Beaufort West and Fraserburg in the central Cape Province. The 450-metre succession consists mainly of vertically accreted floodplain mudrocks with interbedded continuous sheets of fine-grained sandstone that bear evidence of having accumulated by lateral accretion on the inner banks of meandering channels.

The mudrocks contain numerous fossilized skeletons of therapsid "mammal-like" reptiles as well as more primitive cotylosaurs and a few amphibians. Rarely, impressions of *Glossopteris* leaves and equisetalean stems are found although root moulds are relatively abundant. Several types of calcareous nodules and sheets occur in the mudrocks and are interpreted as evidence of calcic palaeosols that formed under semi-arid climatic conditions.

This is an interdisciplinary study that integrates a conventional sedimentary facies analysis with investigations of the taphonomy of *in situ* therapsid fossils and the nature and distribution of palaeosols. Such an approach has not previously been applied to any of the Karoo strata. The results contain descriptive and quantitative information on sedimentary processes, palaeohydrology, absolute time represented in the stratigraphic record and the topography, soils and habitats of the ancient landscape. These are summarized into a palaeoenvironmental synthesis of the Teekloof Formation.

Two facies associations are recognized within the Teekloof Formation. (1) *The channel facies association*: thick (5 - 25 m) laterally accreted sandstones of both single and mutlistoried geometry made up of discrete point-bar and channel-fill sedimentary facies that are characteristic of large, Mississippi-sized, mixed-load meandering rivers. Exceptional and previously undescribed three-dimensional exposures of a large exhumed palaeomeanderbelt were mapped and logged and provide the basis for reconstructing the palaeohydrology and migration behaviour of one of the "Reiersvlei rivers".
(2) *The interchannel facies association*: comprising 10 - 50 m thick intervals of alternating siltstone and fine-grained sandstone sheets with mudstone confined mainly to thin "veneers". The mudrocks represent extended periods of alluviation on exposed semi-arid floodplains between major meanderbelt ridges. Much of

the alluvium was deposited episodically from sediment-laden flood discharge that spilled over both banks of the main channels, across prograding crevasse-splay fans, into narrow distributaries that drained the proximal floodplain and issued into shallow playa-type lakes in the more distal floodbasin. Alluvium that was deposited in each of these subenvironments gained specific sedimentary, taphonomic and pedogenic features that were preserved and are used to distinguish them in the rock record.

Three facies and six subfacies are recognized within the interchannel facies association, each is given an environmental epithet based on comparison with modern floodplain deposits.

Channel bank/levee deposits contain rapidly alternating sandstone to siltstone flood couplets overlying scour surfaces. Distinction is made between inner-bank and outer-bank subfacies based mainly on their inter-relationship with strata of upper point-bar facies and the relief of internal scour surfaces. Vertebrate fossils are generally sparse but locally abundant in some abandoned crevasse channel-fills.

Proximal floodplain facies comprise vertically stacked sheets of fine-grained sandstone, siltstone and minor mudstone with abundant, but dispersed, vertebrate fossils. They often contain one or more tabular crevasse-splay sandstones which are up to 3 m thick, mainly horizontally laminated and usually contain evidence of discontinuous vertical aggradation with possible aeolian reworking. Narrow "shoestring" sandstones form another distinctive subfacies interpreted as the preserved channel-fill deposits of ephemeral, low sinuosity distributaries.

Distal floodbasin facies are made up of thinly bedded sandstone-siltstone couplets with interbedded sharply bounded distal crevasse-splay sandstones. Palaeosurfaces on the upper surface of the sandstone interbeds are rarely preserved beneath claystone veneers and display an array of sedimentary and biogenic structures, including vertebrate tracks, which record shallow water sedimentation followed by stillstand exposure and desiccation. Gypsum "desert rose" crystals and silicified carbonate muds are interpreted as having precipitated on the margins of playa type lakes in the axial depressions of the Teekloof floodbasins.

Comparison of the morphology and petrology of palaeo-caliche nodules in the Teekloof palaeosols with those of sub-recent calcretes suggests that the latter were formed under a semi-arid climate of long warm to hot summers (mean annual temperature 16 - 20 degrees C) and short wet winters (mean annual rainfall 500 - 800 mm).

Maturity of the Teekloof palaeosols may be assessed from palaeocaliche morphology, the degree of clay illuviation and the presence of ped structures in the lower solum. Pedogenic maturity at any site appears to be controlled by the rate of alluvium accumulation and, to a lesser extent, the topographic position.

Taphonomic assessment of 940 vertebrate fossils collected from the study block showed that rocks of the proximal floodplain facies were the most fossiliferous and contained relatively more fully articulated therapsid skeletons than channel bank or distal floodbasin facies. The occurrence of proximal floodplain deposits containing numerous skull-only *Diictodon* specimens was investigated and interpreted as the combined effect of carnivore attack in opening up the neck area to early disarticulation and the fact that after death the lower jaw remained locked in place by the curve of the horn-covered beak thus forming a single heavy and compact unit that resisted entrainment and transportation during subsequent floods. During this investigation it was discovered that some taphonomically anomalous occurrences of curled-up and paired *Diictodon* skeletons resulted from their entrapment and burial within underground burrows. The patterns of bone weathering and skeletal disarticulation in the different floodplain facies is interpreted as a function of the duration of post-mortem exposure on the floodplain surface.

It is concluded that the main factor determining the style and rate of sedimentation, the degree of skeletal disarticulation and weathering of bones and the maturity of palaeosols in different parts of the floodplain was distance of the floodplain site from the nearest major channel.

On a larger scale, two major first order fining-upward cycles make up the Teekloof Formation comprising a lower channel-sandstone rich interval followed by a dominantly mudrock interval. These variations are interpreted as a reflection of disequilibrium between alluvial plain morphology and total energy supply brought about by differential rates of subsidence between adjacent regions of the basin. It is concluded that because they result from natural shifts in the drainage nets their controls are autocyclic rather than allocyclic.

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1. INTRODUCTION

The intracratonic main Karoo Basin covers almost two thirds of the land surface of South Africa, an area of some 300 000 square km (see inset of Fig. 1). It contains a relatively continuous sequence of continental sedimentation that lasted from the Permo-Carboniferous (280 Ma) through to the earliest Jurassic (180 Ma). These rocks, known collectively as the Karoo Sequence accumulated under a range of climatic regimes, from polar to warm-desert, and within a variety of tectonically-controlled depositories.

The Karoo Sequence succession is most completely preserved in the central parts of the basin, surrounding and including the Lesotho highlands, where its average thickness is 1 200 m. In the southern Karoo, the succession is incomplete yet the Karoo strata are up to 4 000 m thick. Here the upper parts of the succession have been removed by denudation that may have begun as long ago as the late Triassic, and is continuing today. Mainly physical weathering under semi-arid climatic conditions has laid bare large areas of fossil-bearing strata belonging to the Beaufort Group, providing palaeontologists with unlimited collecting grounds for the longest and most complete fossil record of therapsid reptiles in the world.

1.1. LOCATION OF STUDY AREAS

The Beaufort Group strata occur midway through the Karoo Sequence and, in the southern part of the basin, they comprise some 3 000 m of alluvial sediments.

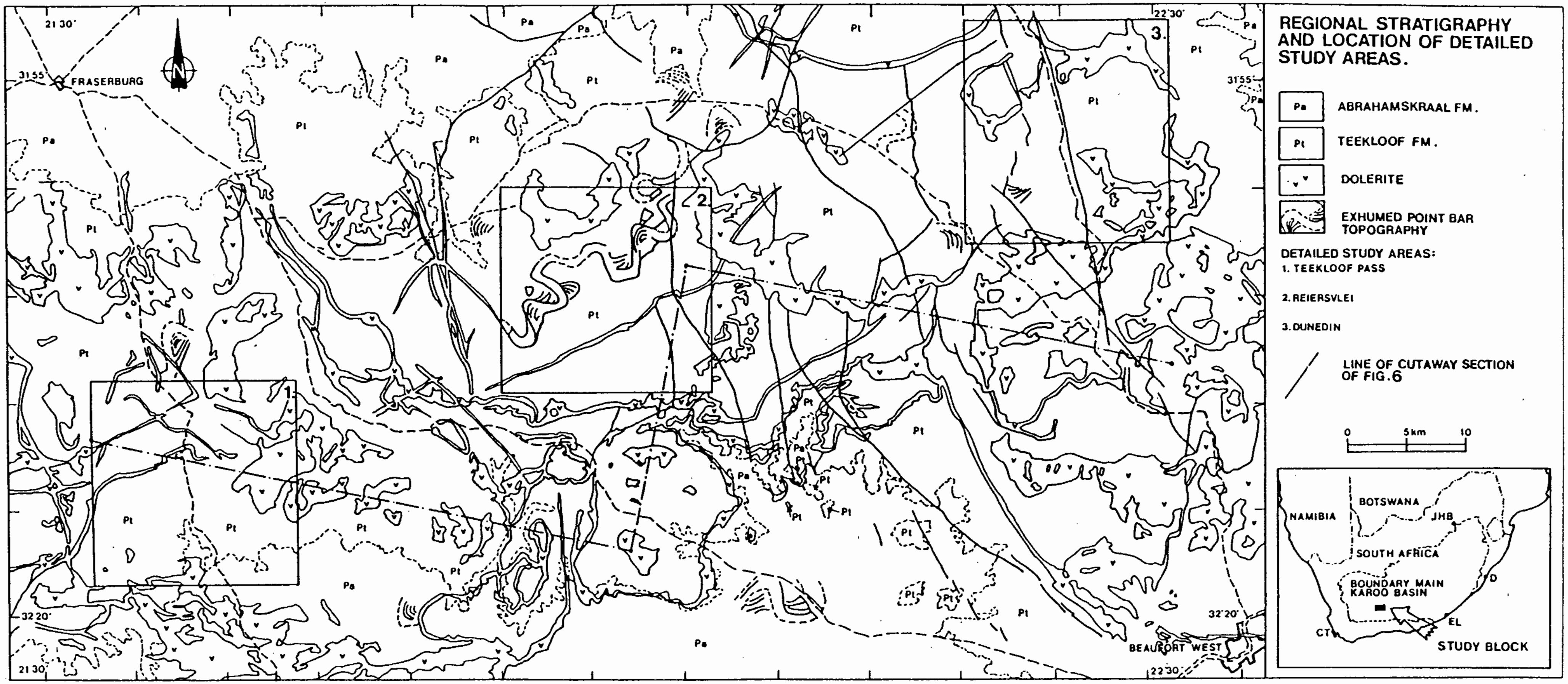


FIG. 1 Regional stratigraphy and location of detailed study areas.

The Teekloof Formation, on which this study is based, is in the lower part of the Beaufort succession outcropping mainly in a prominent east-west trending, dolerite-capped, erosional escarpment between the towns of Graaff-Reinet (32 degrees S, 25 degrees E) and Sutherland (32 degrees S, 21 degrees E) in the southwestern Karoo (See Fig. 1).

Three field areas were selected for this study, situated midway along this escarpment between the towns of Beaufort West and Fraserburg (Fig. 1) covering the continuous vertical exposures within the Nuweveld escarpment as well as large planimetric exposures of flat-lying strata on top. They include the complete stratigraphic succession of the Teekloof Formation which is approximately 450 m in this part of the basin and covers an area large enough for the findings of this study to be representitive of the Teekloof Formation as a whole.

1.2. PREVIOUS WORK, AIMS AND METHODS

Before the discovery of uranium near Beaufort West in 1969, most of the research into depositional environments of the Beaufort Group had been conducted by palaeontologists. As far back as 1907, Robert Broom envisaged the large inland Karoo basin becoming silted-up by aggrading floodplains. Later, Du Toit (1918), Haughton (1919), Von Huene (1925), Case (1926), Colbert (1963) and Boonstra (1969) agreed that the mammal-like reptiles lived on, and were preserved in, muddy floodplain deposits. These workers did not identify the large lenticular sandstone bodies as fluvial channel deposits. This observation was made by Johnson (1966) and Ryan (1967) and later published by Keyser (1970). The first palaeoecological observations of the Lower Beaufort were made by Hotton (1967), Keyser (1966, 1970) and Kitching (1977) but their main research interests remained palaeontological.

Roussouw and De Villiers (1952) were the first to map the Lower Beaufort in the Merweville district and to describe a sandstone-rich interval, the "Poortjie sandstone", that later proved to be the main uranium-bearing strata in the area.

As part of their onshore petroleum exploration program, SOEKOR drilled several stratigraphic boreholes in the southwestern Karoo which proved invaluable for probing the depth of the Karoo sequence and the upper part of the Cape Supergroup in the southern Karoo Trough (Winter and Venter 1970). The presence of radioactive mineralization in the Lower Beaufort was first recorded in 1967 when thorium anomalies were encountered during routine radiometric logging of a SOEKOR borehole near Merweville.

Between 1969 and 1979 the discovery of uraniferous outcrops in the Beaufort West area attracted exploration teams from the United States, Canada and South Africa. They located and prospected hundreds of uranium occurrences, mainly in the 300 km belt between Beaufort West and Sutherland. These companies provided a steady stream of subsurface information from their prospect drilling which promoted several research projects including the first sedimentary facies analyses of the Lower Beaufort strata (Turner 1975, 1978; Kubler, 1977; Pretorius, 1977; Stuart Williams, 1981).

The need to understand the nature and genesis of the uranium mineralization resulted in detailed mineralogical investigations of the sandstones and their uranium ores (Moon, 1974; Von Backstrom, 1974, 1976; Ho Tun, 1979; Jakob, 1979; Wallace and Van de Merwe, 1978, 1979). Significant uranium mineralization occurs mainly in the basal portions of high sinuosity channel sandstones in close association with carbonaceous debris. Therefore, the bulk of commercially-generated research during the post-1969 period was based on the larger sandstone bodies (eg. Anderson and Fraenkel, 1979; Eddington and Harrison, 1979) and tended to ignore the rest of the sedimentary sequence comprising the volumetrically dominant, but economically non-viable, overbank mudrocks.

During the period of intensive exploration, the Geological Survey of South Africa and the Atomic Energy Board, now Atomic Energy Corporation (AEC), were conducting special research projects in the southern Karoo to assess the strategic importance of the uranium discovery (Von Backstrom, 1974, 1976; Toens and Le

Roux, 1978; Le Roux *et al.*, 1979) and to investigate the mode of occurrence (Moon, 1974; Horowitz, 1976; Le Roux, 1982) and ore genesis (Martini, 1974; Jakob, 1979; Beeson, 1980) of the uranium. At the same time the Geological Survey undertook regional geochemical, airborne magnetic and radiometric surveys (Stettler, 1981, 1983, 1984a, 1984b) and regional geological mapping (Johnson and Keyser, 1979), although the published compilations became available only after much of the exploration activity had finished. Regional biostratigraphic work continued with a special project on the problem of basinwide mapping of stratigraphically equivalent strata to the uraniferous outcrops near Beaufort West (Keyser, 1977; Keyser and Smith, 1979).

Some micropalaeontological and palynological studies were carried out but the lack of well-preserved specimens and the degree of regional metamorphism made the results inconclusive (Stapleton, 1975, 1977).

Post-1979 research in the southwestern Karoo was still mainly based on uranium prospects but included much more outcrop data presented in two-dimensional cliff-section logs (Stear, 1980; Cole, 1980; Le Roux, 1985). These studies used a facies approach that included the mudrock sequences but relied upon the channel deposits for much of the hydrodynamic interpretation. Smith (1980, 1981) made the first attempt at a facies study of the overbank deposits and included the taphonomy of vertebrate fossils as an aid to hydrodynamic interpretations. McPherson and Germs (1979) presented some preliminary observations of the mudrock-hosted palaeopedogenic carbonate nodules of the Lower Beaufort but unfortunately they did not complete the study.

Recent research on the Lower Beaufort strata of the southwestern Karoo includes an evaluation of the timing, nature and distribution of uranium mineralization in the Karoo Basin as a whole (Turner 1985), and an assessment of the role of roll-front type uranium mineralization in the channel sandstones of the Beaufort West area (Stuart Williams and Taylor, 1983). Cole (1986) has continued to investigate the distribution and genesis of molybdenum in the Lower Beaufort and its association with the uranium mineralization. Rubidge (1988), Jordaan (1981, 1987) and Wickens (1984, 1987) are concentrating on the Beaufort/Ecca transition in the southwestern Karoo and its definition in palaeoenvironmental, palaeontological and lithological terms. Cole (1987) is also formulating a new lithostratigraphic scheme for the Beaufort Group based on three major fluvial systems that originated from different source areas.

Smith (1987) described the morphology and depositional history of a large exhumed meanderbelt in the Beaufort West area and compared the calculated palaeohydrologic parameters with those of the modern Indo-Gangetic alluvial plain. In another paper Smith (1987a) presented evidence for burrowing activity by therapsid reptiles in the Lower Beaufort strata which proved to be strikingly similar to that of an ancestral beaver of Miocene age from North America.

The purpose of this investigation is to improve our understanding of the palaeoenvironmental conditions that prevailed in the southwestern Karoo Basin whilst the Lower Beaufort Teekloof Formation sediments were accumulating and to make predictions as to their effect on the distribution of uranium ore in the succession.

Three different fields or sub-disciplines of earth sciences are involved in this study: fluvial sedimentology, palaeopedology and vertebrate taphonomy. Each discipline requires a different approach to fieldwork and favours different types of exposure but, wherever it was possible, data for all three topics were collected from the same outcrops.

This study is modelled on the more recent work of Bown and Kraus (1981, 1981a, 1987) and Kraus (1987) in the Eocene Willwood Formation of Nebraska, and Behrensmeyer and Tauxe (1982) and Behrensmeyer (1987) in the Miocene Siwalik Group of northern Pakistan. These workers have successfully integrated traditional fluvial facies analysis with studies of vertebrate taphonomy and palaeosols to gain new insight into the time resolution of alluvial stratigraphy, the reconstruction of the ancient floodplain topography and the palaeoenvironmental conditions under which these sediments accumulated.

The field data on which this study is based were collected during the 1984 - 1987 field seasons. The geological maps (Appendix Figs. 1, 2 and 3) were compiled from 1:50 000 aerial photographs supplied by the Trigonometrical Survey of South Africa. Topocadastral maps of the same scale provided a base on which to plot photogeological contacts in order to compensate for distortion and scale variation in the stereoscopic photographs. Details of lithologies and contacts were checked and mapped from ground observation.

In the field, three times enlargements of the 1:50 000 photographs to a scale of approximately 1:16 500, provided an adequate base-plan for recording positional information such as section and fossil localities etc. Mapping and palaeocurrent readings on planimetric sandstone surfaces were recorded on 1:5 000 scale graph paper base-plans. Using a telescopic alidade and range rods, a rudimentary 100 metre square grid was beaconed and flagged to provide local positional reference points. The grid was systematically walked to record palaeocurrent and sedimentological information of all outcrops encountered along the +/- 65 line kilometres.

Selected cliff-section outcrops of both channel and interchannel facies were recorded either on two dimensional panel sections or 1 dimensional columnar logs. Some panel section base-plans were compiled from sequential photographs of the outcrop, others were documented directly onto scaled graph paper by continuously recording discontinuities and large scale structures between detailed vertical sections spaced every 25 m. Cliff sections were normally measured with a suspended tape measure. Some mudrock sections on non-vertical slopes involved the use of a graduated staff and abney level.

Macrostratigraphic panel sections (Appendix Fig. 4), aimed at demonstrating the alluvial architecture of the major lithostratigraphic subdivisions of the Teekloof Formation, were constructed from regional photogeological reconnaissence followed up with detailed geological transects along drainage channels through the succession.

The taphonomic assessment of therapsid fossils located in the study areas involved a suite of observations and measurements that needed to be made on site, before the fossil was lifted, and which were recorded on especially prepared taphonomic data sheets (see Appendix Fig. 23). Fossils found in cliff sections selected for microstratigraphic documentation were marked with spray-painted boulders so that their positions would be visible on the sequential black and white photographs. Fossils that were considered worthwhile preparing have been taken into the collections of the Department of Karoo Palaeontology of the South African Museum, others that were either too fragmentary or too badly weathered, were taphonomically assessed and left where they were found.

The first part of this report puts the Teekloof Formation into its global setting and presents what is known of the major tectono-climatic controls and broad depositional environments of the southern Karoo Basin. This is followed by a description of the various fluvial facies identified in the field areas with emphasis on three dimensional geometries of rock units and interpretation of sedimentary processes. Detailed descriptions of palaeosol profiles in the floodplain facies are then presented and discussed with respect to palaeotopography and climate. The results of taphonomic analyses of some 1 000 therapsid fossils found in the study areas during the course of this research are reported within the context of the previously defined sedimentary facies.

In the final chapters the results of these investigations are summarized and incorporated into a detailed palaeoenvironmental reconstruction of the Teekloof Formation. The possible role played by pedogenesis and channel bank vegetation in the localization of uranium within the channel sandstones is discussed.

Some of the findings of this research have already been published, while others are still in press. Following is a list of these publications, parts of which are reproduced in this report.

Smith, R.M.H., 1987, Morphology and depositional history of exhumed Permian point-bars in the southwestern Karoo, South Africa. *Jour. Sed. Petrology*, **57**, p.19-29.

Smith, R.M.H., 1987, Helical burrow casts of therapsid origin from the Beaufort Group (Permian) of South Africa. *Palaeogeog. Palaeoclimatol. Palaeoecol.*, **60**, p. 155-170.

Smith, R.M.H., (in press), A review of stratigraphy and sedimentary environments of the Karoo Basin of South Africa. In: Kogbe, C.A. and Lang, J. eds., *Continental Deposits of Africa*. Pergamon Press, Oxford.

Smith, R.M.H., (in press), Alluvial paleosols and pedofacies sequences in the Permian Lower Beaufort of the southwestern Karoo Basin, South Africa. *Jour. Sed. Petrology*.

1.3. PALAEOGEOGRAPHIC AND TECTONIC SETTING OF THE SOUTHERN KAROO BASIN

"The tectonic framework of any particular basin of deposition and its source areas has a direct and major bearing on the quantity and quality of the sediments which accumulate in it" (Krumbein & Sloss, 1963). To fully understand the stratigraphy and sedimentary environments of a particular portion of basin-fill, in this case the Beaufort Group of the Karoo Basin, it is necessary to first view the evolution of the basin as a whole in its global context.

The Karoo Basin was originally part of southwestern Gondwana and was the largest of numerous separate or partly connected basins in this region that are now scattered upon the drifted continents of Africa, Antarctica and South America. Figures 2, 3 and 4 illustrate the changing palaeolatitudes of the Gondwanan continents and their major orogenic belts in relation to subsiding tectono-sedimentary terrains during the accumulation of the Karoo Supergroup and equivalents.

Rust (1975) noted that in the African fragment of Gondwana, broadly similar tectonic and sedimentary conditions operated essentially simultaneously over large areas, producing several basins which are very similar in character. He recognizes 2 such "tectono-sedimentary terrains" in southern Africa, the Karoo terrain and the Zambezian terrain.

The Karoo terrain covers the southern African continent west of 25 degrees E and is characterized by basin and swell tectonics whereas the Zambezian terrain, extending over the eastern sector, comprises a series of disconnected yoked fault basins. The type Karoo Basin, the Kalahari or Botswana Basin, the Congo Basin and Etjo Basin make up the Karoo terrain and the Mid Zambezi, Lower Zambezi, Luangwa and East African Basins make up the Zambezian terrain.

The intracratonic Karoo Basin in which this study is based originally covered a considerably larger area than the remnant 300 000 square km preserved in South Africa (see Fig. 2). It is made up of several tectonically defined sub units within two main troughs, an E-W trending southern Karoo Trough and a NE-SW trending Natal Trough.

Although there is general unconformity between the Cape and Karoo Supergroups in South Africa the basin development was in fact a continuous process. These two main troughs had been active since the early Palaeozoic and were the result of incipient rifting along deep seated Pan-African structural trends (Tankard *et al.*, 1982). Following deposition of the Cape Supergroup in the pre-Karoo basin there was a +/- 20 million year period of uplift and erosion. During this time this part of the Gondwanan supercontinent drifted into the southern polar regions (Fig. 2) resulting in a major glaciation at the end of the Carboniferous and the beginning of Karoo sedimentation (Dwyka Formation Fig. 5).

After glaciation, an extensive shallow lake remained fed by large volumes of meltwater. Black clays and muds accumulated on the submerged glaciated platform to the south under cool climatic conditions (Lower Ecca). Deformation of the most southerly rim of the basin during the initial stages of the Cape Fold Belt orogeny resulted in mountain ranges far to the south (Fig. 3). This deformation was probably caused by the subduction of the palaeo-Pacific plate beneath the Antarctic plate forming an alpine-type mountain chain along the southern margin of Gondwana (Fig. 3). Material derived from these mountains as well as from stable craton uplands to the west and north-east, was deposited on large deltas that prograded into the Ecca Sea (Upper Ecca). Later, as the southern orogenic belt migrated northwards the prograding deltas coalesced to fill a major part of the basin after which fine-grained fluvial deposits of the Beaufort Group began to dominate the depository. During the early Triassic, intermittant tectonic pulses in the encroaching proto-Precordillerian orogenic belt caused coarse-grained debris fans (Katberg Sandstone and Molteno Formation) to prograde into the centre of the basin which was for the most part drained by fine-grained meanderbelts and semi-permanent lakes (Fig. 5).

Following deposition of the Beaufort Group climatic aridification combined with a tectonically shortened, progressively shrinking basin, dominated the sedimentary regimes. Playa-lake and wadi type environments (Elliot Formation) finally gave way, by the Late Triassic, to a dune-sand dominated system (Clarens Formation, Fig. 5). By this time the northward migration of the Cape Fold Belt into the south of the Karoo Basin had reached its maximum and had truncated the southern margin of the basin (Fig. 4) throwing the incorporated lower Karoo strata into a series of tight E-W trending folds. Erosion of these newly uplifted areas resulted in the coarse-grained debris fans of the Katberg member and Molteno Formation.

The Cape Fold Belt is reconstructed as part of a continuous orogenic belt extending the length of the southern margin of Gondwana, named by Du Toit (1937) as the Gondwanide Orogeny. Craddock (1975) links the Cape orogen to the Antarctic Ellsworth orogen based on similarities in deformation structures and granitic intrusives.

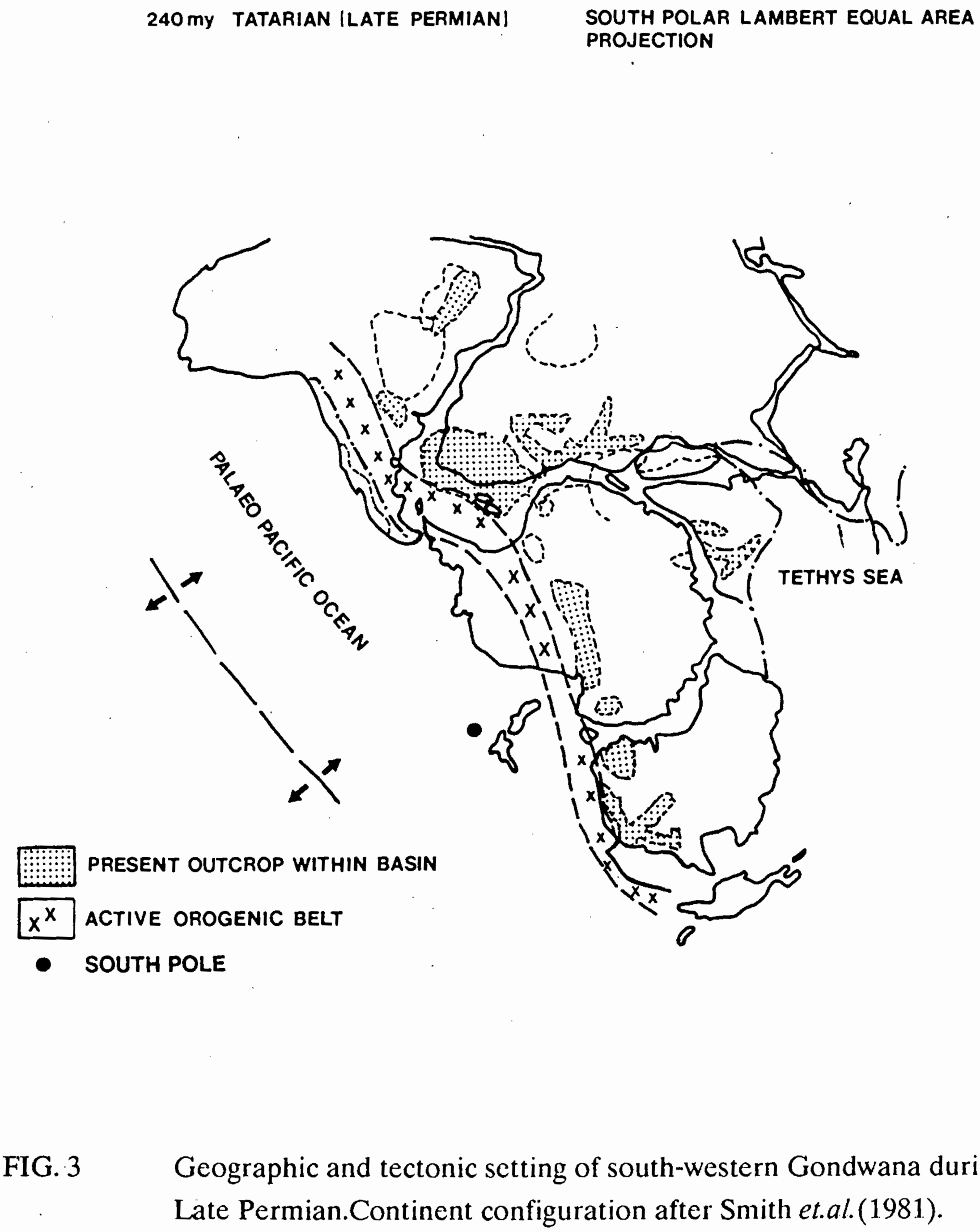


FIG. 3 Geographic and tectonic setting of south-western Gondwana during the Late Permian. Continent configuration after Smith *et.al.* (1981).

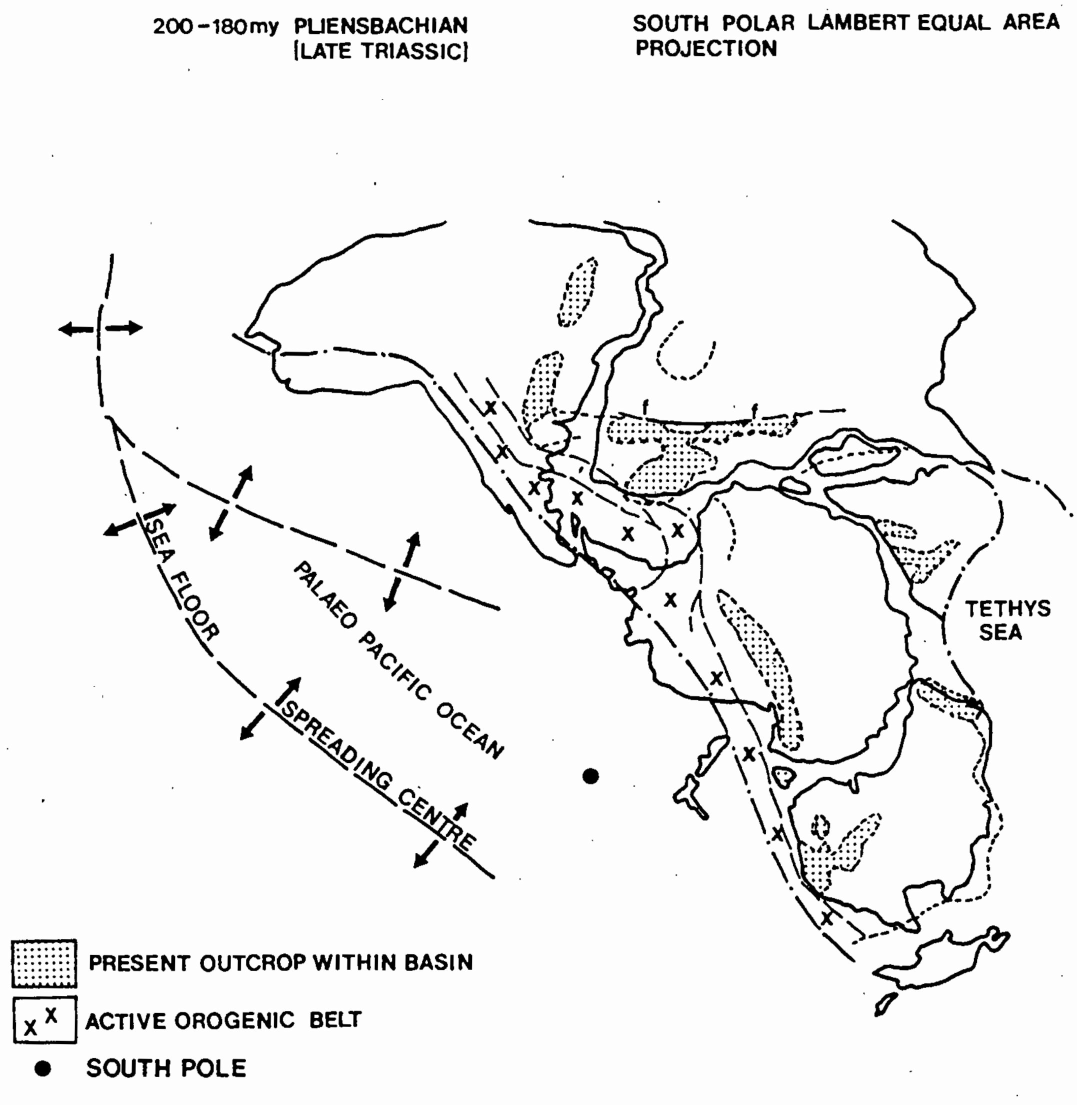


FIG. 4 Geographic and tectonic setting of south-western Gondwana during the Late Triassic.Continent configuration after Smith *et.al.*(1981).

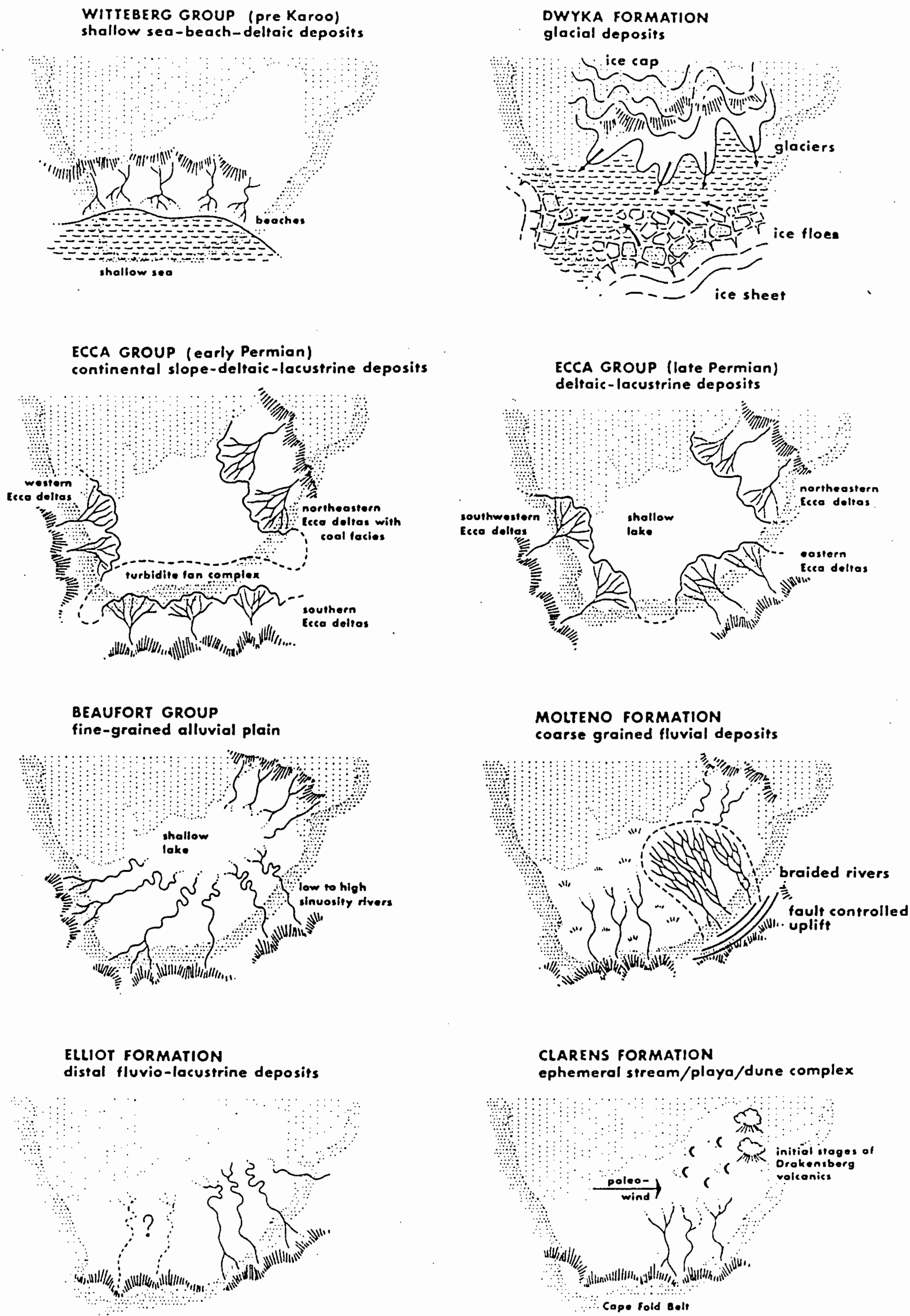


FIG. 5 Palaeogeography of the major lithostratigraphic units of the Karoo Sequence. Adapted from Visser (in press).

The mechanism by which collision-type folding of the Cape orogen could occur at least 1 000 km from the continental plate margin is problematic but may be attributed to flat-plate subduction (Lock, 1980; Nicholaysen 1985). If the palaeo-Pacific oceanic crust had been subducted at a low angle beneath the Gondwanan plate it may have transferred the stresses of convergence through the smaller Falkland micro plate to the interior, forming the compressional Cape Fold Belt.

Although the southern margin of the Karoo Basin has been tectonically shortened it is apparent from the tremendous thicknesses of Cape and Karoo strata in the southern Karoo Trough that this was the most rapidly subsiding depository in the basin. This subsidence is attributed by Tankard (1982) to abortive rifting along major crustal weaknesses during the early Palaeozoic. It is possible, however, that the northwardly migrating orogenic belt linked to the subduction of the palaeo-Pacific crust may have caused continued and gradually increasing subsidence in its foreland basin. This may have been brought about by a mechanism similar to that described by Walcott (1970) whereby crustal loading resulting from tectonic thrusting in the source areas causes isostatic subsidence that extends beyond the area of loading into the adjacent basin. Such a mechanism could also account for the apparent asymmetry in the infilling of the southern Karoo Trough.

Within the Karoo tectono-sedimentary terrain (Rust 1975), north of the southern Karoo Trough, smaller partly interconnecting basins developed through subsidence, possibly as a result of mantle phase changes, sedimentary loading, or a lag in isostatic rebound after the Dwyka glaciation (Tankard *et al.*, 1982). Differential subsidence between these basins and the intervening stable ridges caused local variations in depositional style and rates of sediment accumulation.

In the eastern part of the basin, within the Zambesian terrain, fault-bounded rifts and grabens created more restricted short-lived depositories that filled with locally derived, flysch-type deposits.

Gradual climatic changes within the basin and its source areas imposed gradual but major changes on the style of Karoo sedimentation. During the course of its infilling, the main Karoo Basin drifted from polar (70 degrees S) to tropical (30 degrees S) latitudes passing through polar, cold temperate, warm temperate and warm desert climatic zones (Visser, in press). Superimposed on this general warming were global climatic fluctuations due in part to the presence or absence of ice caps, the orientation of the supercontinents in relation to atmospheric and oceanic circulation patterns, sea level changes, and possibly cyclic changes in solar radiation (Frakes 1979).

On a basinal scale these global climatic trends were probably modified by the continental setting of the Karoo Basin surrounded, as it was, by large land masses and a mountain range. This would have had a general meteorologic drying effect which may have been enhanced by a rain shadow caused by the southern mountain range interrupting the northward circulation of polar air (Visser, in press).

1.4. STRATIGRAPHY OF THE LOWER BEAUFORT IN THE SOUTHWESTERN KAROO BASIN

1.4.1. Lithostratigraphy

Regional lithostratigraphic subdivision of the Beaufort Group in the southwestern Karoo is difficult due to the general monotony of lithologies. The succession is made up of some 3 000 m of siltstone and mudstone with interbedded fine-grained sandstones. Stratigraphic correlation is hampered by the lack of continuous marker beds, the lenticular geometry of sandstone bodies, the extensive intrusion of the northern outcrop by dolerite sills and dykes and the complex structural deformation of the southern outcrop.

The base of the Beaufort Group is transitional with the underlying Ecca Group (Table 1). In the southern Karoo Trough the Ecca deltas made the transition from delta-top to alluvial plain environments before those of the northern and eastern margins of the Karoo Basin. This resulted in a basinwide diachroneity in the contact between the upper Ecca beds and the lowermost Beaufort (Johnson, 1966; Keyser *et al.*, 1979; Jordaan, 1981).

Debate continues as to the lithological criteria defining the base of the Beaufort Group within the Ecca/Beaufort transition. Initially Roussouw and De Villiers (1952) and Mountain (1964) used the first appearance of purple mudstone as a mappable definition of the base of Beaufort strata. Johnson (1966, 1976) found the purple mudstone criteria unusable in the eastern Cape and Natal where he defined the boundary on sandstone texture and thickness. Keyser and Smith (1979) concluded that the first occurrence of purple mudstone, although not always developed, is evidence of prolonged sub-aerial exposure of the floodplain and offers a recognizable indicator of Beaufort-type depositional environments.

The present consensus, however, favours a boundary drawn at the top of the sub-aqueous lower delta-plain deposits, coinciding with the interpreted "palaeoshoreline" (Rubidge, 1987). The overlying basal Beaufort beds are distinguished on various lithological and palaeontological criteria including the presence of non-transported therapsid fossils, mudcracks, raindrop impressions, gypsum rosettes, brown-weathering calcareous nodules and complete plant fossils, some in growth position (Rubidge, 1987). Palaeontologically, the base of the Beaufort Group is defined by the first occurrence of mammal-like reptile fossils. The occurrence of therapsids in beds mapped as Ecca (Barry, 1970; Rubidge *et al.*, 1983; Rubidge 1984, 1985) have all recently been re-assigned to Beaufort Group strata (Rubidge, 1987, 1988).

The top of the Beaufort Group was defined by Du Toit (1954), and remains today, as the base of the "first glittering sandstone" of the Molteno Formation. The "glittering" effect is caused by quartz overgrowths in the pore spaces of these medium-to coarse-grained continuous sandstone sheets.

Rogers (1905) arbitrarily subdivided the Beaufort Group rocks into lower, middle and upper stages and, even though this was officially rejected by S.A.C.S. (1976), the term "Lower Beaufort" is still widely used today. Later Du Toit (1954) described the top of the middle stage consisting of a thick feldspathic sandstone (later named the Katberg Sandstone Formation by Johnson (1966)) and referred to the overlying strata as the "Burghersdorp Beds" (later converted to Burgersdorp Formation by Johnson (1966)).

In 1976 the South African committee for stratigraphy accepted Johnson's (1976) twofold division of the Beaufort Group into a lower Adelaide Subgroup (previously Lower Beaufort) and an upper Tarkastad Subgroup (previously Middle and Upper Beaufort), the boundary between the two being defined by the base of the Katberg Sandstone Formation.

Working in the western part of the southern Karoo Trough (west of 26 degrees E), Keyser and Smith (1979) proposed a twofold division of the Adelaide Subgroup, a lower Abrahamskraal Formation and an upper Teekloof Formation (Table 1). The distinction between these formations was based on a range of criteria including sandstone/mudrock ratios, mudstone colour, presence of "chert" bands, nature of calcareous nodular material and the geometry, texture and organic content of the channel sandstones.

Turner (1978) divided the Adelaide Subgroup into three superimposed sedimentary facies associations representing a gradual reduction in fluvial energy, with a transition from low-sinuosity (Ecca/Beaufort transition) to high sinuosity (Abrahamskraal Formation), and finally floodplain dominated sedimentation of the Teekloof Formation.

The Teekloof Formation attains a maximum thickness of 1 000 m, thinning considerably toward the northern limb of the southern Karoo Trough (Fig. 7) and eastwards where it grades laterally into the Balfour Formation (Keyser and Smith, 1979). The succession is dominated by green, grey and maroon mudrocks with thin but extensive laterally- accreted channel-sandstone bodies. Spectacular point-bar topography is displayed on the top of some exhumed sandstones (Kubler, 1977; Smith, 1987), illustrating highly sinuous palaeochannel patterns. The preferential preservation of upper-phase planer-bedding and the irregular

GROUP	FORMATION			VERTEBRATE BIOZONES
Drakensberg (volcanics)				
	Clarens			
(previously Stormberg)	Elliot			Massospondylus Euskelosaurus
	Molteno			
Beaufort	SW	SE	NE	
Tarkastad Subgroup		Burgersdorp	Otterburn	Kannemeyeria-Diademodon
		Katberg	Belmont	Lystrosaurus-Thrinaxodon
Adelaide Subgroup		Balfour	Estcourt	Dicynodon lacerticeps-Whaitsia
	Teekloof			Aulacephalodon-Cistecephalus
		Middleton		Tropidostoma-Endothiodon
				Pristerognathus-Diictodon
	Abrahamskraal	Koonap		Dinocephalian (Eodicynodon)
Ecca		Waterford	Volksrust	
		Fort Brown	Vryheid	
	Laingsburg	Ripon		
	Vischkuil		Pietermaritzburg	
		Collingham		
		Whitehill		
		Prince Albert		
	Dwyka			

TABLE 1 Stratigraphy of the Karoo Basin. Vertebrate biozones after Keyser and Smith (1979), Rubidge (1988) and Kitching and Raath (1984).

accretion topography in these point-bars is interpreted as evidence for a "flashy" discharge regime (Stear, 1978, 1983; Smith, 1981, 1987; Turner, 1984). Recognition of ephemeral stream sedimentation and playa-type gypsum precipitation (Keyser, 1966; Stear, 1978) indicates semi-arid climatic conditions during Teekloof accumulation. This interpretation is supported by the mode of occurrence and distribution of palaeopedogenic carbonates (McPherson and Germs, 1979; Smith, 1980, 1981) which are comparable to Quaternary caliche formed under warm to hot mean annual temperatures (16 - 20 degrees C) with highly seasonal rainfall in the 100 - 500 mm range (Goudie, 1973).

The base of the Teekloof Formation, as mapped by the Geological Survey of South Africa on the 1:250 000 scale 3220 Sutherland and 3222 Beaufort West geological maps, co-incides with the base of an arenaceous member known as the Poortjie Sandstone Member (see Fig. 1). Roussouw and De Villiers (1952) first recognized and mapped this +/- 60 m thick succession which contains a much higher proportion of sandstones than the strata above and below. This interval has since been the subject of intensive exploration following the discovery of significant uranium mineralization within the thicker channel deposits.

In the southwestern Karoo, the Teekloof Formation has an informal and strictly local stratigraphic nomenclature based on sandstone-rich and sandstone-poor stratigraphic intervals (Turner, 1979, Fig. 6). Lithostratigraphically the 400 m succession covered in all three study areas lies in the lower half of the Teekloof Formation and spans the lower boundary with the Abrahamskraal Formation (see Fig. 7). From the Poortjie Sandstone or "Paalhuis member" the section passes upwards through the predominantly argillaceous "Hoedemaker member", the arenaceous "Oukloof member" and the lower part of a mudrock dominated "Steenkampsberg member" (see Fig. 6).

Palaeocurrent analyses indicate that within the southwestern Karoo Basin there were three main provenance areas during the accumulation of the Adelaide Subgroup - a southeasterly, southwesterly and west-northwesterly (Cole, D.I., pers. comm.). Each system deposited discrete "sandstone packages", being clusters of

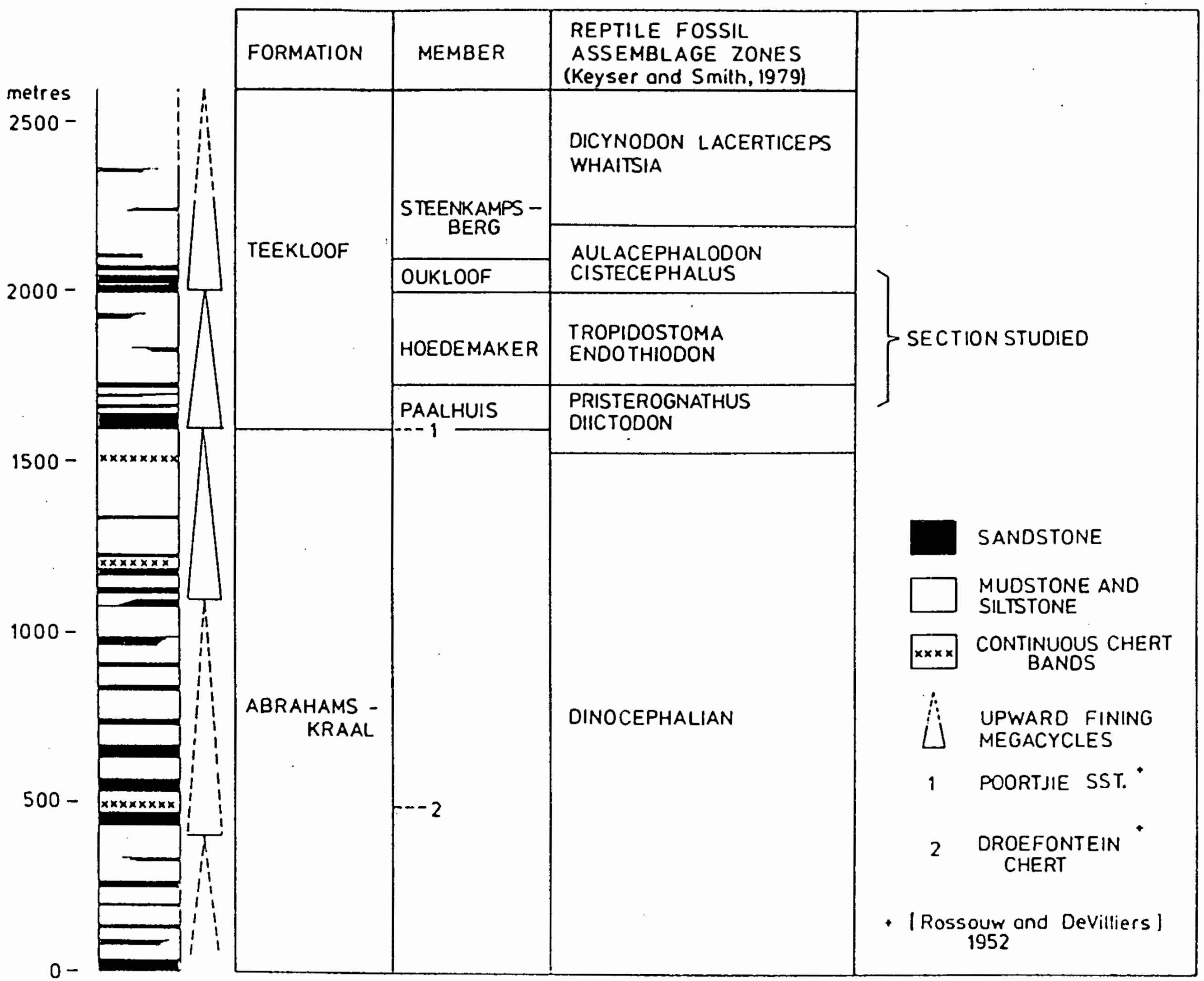


FIG. 7 The formal and informal stratigraphy of the Adelaide Subgroup, west of 25 degrees E, showing fining-upward megacycles and the interval studied.

sandstone bodies totalling 50 - 300 m thick separated by predominantly mudrock intervals (Fig. 7 and Appendix Fig. 4). These are described as fining-upward megacycles by Visser and Dukas (1979) and Stear (1980) and it is these that have given rise to the informal stratigraphic scheme described above. Cole recognizes six packages in the southeast and southwest systems and only one in the west-north-west system restricted to the northern limb of the southern Karoo Trough. The study areas lie within the south-westerly sourced system and include portions of two such fining-upward megacycles (Fig. 7).

1.4.2. Biostratigraphy

The mudrocks of the Lower Beaufort contain abundant fossilized skeletons of therapsid reptiles or so called mammal-like reptiles. The latter term refers to their intermediate phylogenetic position between reptiles and the first mammals. The whole therapsid group became extinct worldwide at the end of the Triassic and are, therefore, only known from their fossilized skeletons, footprints, burrows etc. By far the richest therapsid-bearing beds in the world are those of the southwestern Karoo which contain hundreds of species belonging to five major taxonomic groups, namely: Dinocephalia; Dicynodontia; Gorgonopsia; Therocephalia; Cynodontia. Less common are the primitive cotylosaurs such as *Eunotosaurus* , *Pareiasaurus* and *Owenetta*, and flat-headed amphibians such as *Rhinesuchus*.Very rare components of the fossil fauna include scaloposaurs and dromosaurs, small therapsids of uncertain affinity, and millerettids, a problematic group of small cotylosaurs. Freshwater fish (*Atherstonia* sp) and non-marine bivalves (*Palaeomutela* sp) are also found in these rocks in restricted areas.

There is a general paucity of fossilized plants in the Teekloof Formation that can be explained only by preservation failure because root traces are very common. Those that have been preserved include impressions of equisetalean stems and leaves (*Schizoneura* and *Phyllotheca*), small *Glossopteris* leaves and silicified tree trunks (*Dadoxylon*).

The abundance and variety of mammal-like reptile fossils has attracted the attention of several stratigraphic palaeontologists over the past century. Seeley (1892) was the first to propose a lower "Zone of Parieasaurs", a middle "Zone of Dicynodonts" and an upper "Zone of specialized Theriodonts". In 1909, Broom introduced his zonal scheme which was generally accepted until 1970, when it was revised by Kitching.

Broom's (1909) zones were linked to Rogers' (1905) stages as follows:-

Cynognathus	Zone	)	Upper Stage	)	
Procolophon	Zone	)		)	
				)	
Lystrosaurus	Zone	)	Middle Stage	)	Beaufort Series
				)	
Cistecephalus	Zone	)		)	
Endothiodon	Zone	)	Lower Stage	)	
Tapinocephalus	Zone	)		)	

Kitching (1970) found *Procolophon* in strata containing the zone fossil *Lystrosaurus*, thus proving it to be unusable as a range-zone fossil. He also proved that the stratigraphic ranges of *Endothiodon* and *Cistecephalus* overlapped, leading him to reject the *Enthothiodon* Zone. Kitching's (1970) revision of the Beaufort Group biozonation is as follows:-

Cynognathus	Zone	)	Upper Beaufort	)	
				)	
Lystrosaurus	Zone	)	Middle Beaufort	)	
				)	Beaufort Series
Daptocephalus	Zone	)		)	
Cistecephalus	Zone	)	Lower Beaufort	)	
Tapinocephalus	Zone	)		)	

In 1979, Keyser and Smith proposed a new biozonation scheme for the Lower Beaufort (Adelaide Subgroup). They applied the concept of faunal assemblages to their collection of some 2 500 therapsid fossils from the southwestern Karoo (west of 24 degrees E) and were able to produce a workable biozonation as follows:-

Dicynodon/Whaitsia Assemblage Zone
Aulacephalodon/Cistecephalus Assemblage Zone
Tropidostoma/Endothiodon Assemblage Zone
Pristerognathus/Diictodon Assemblage Zone
Dinocephalian Assemblage Zone

The relationships between the current biostratigraphic and lithostratigraphic schemes for the Lower Beaufort west of 26 degrees E, are summarized in Table 1. Biostratigraphically, the succession covered by the study areas ranges from the upper part of the *Pristerognathus/Diictodon* Assemblage Zone, through the *Tropidostoma/Endothiodon* Assemblage and the *Aulacephaldon/Cistecephalus* Assemblage Zone into the lower parts of the *Dicynodon/Whaitsia* Assemblage Zone.

A total of 940 therapsid fossils were found in the study areas during the course of this study. These are plotted onto the detailed biozonation maps included in the Appendix Figs. 19, 20 and 21. All the fossils collected have been accessioned by the South African Museum, Cape Town (SAM numbers). Lists of field identifications and locality details of each fossil are included in Appendix Fig. 23.

2. FLUVIAL FACIES ANALYSIS

2.1. DEFINITIONS

Modern usage of the term "facies" by clastic sedimentologists has led to much argument as to its definition. It has, therefore, become necessary to clarify the facies definition that is being adopted for a particular study as well as the methods by which the facies are analysed.

The facies definition adopted for this study is that proposed by De Raaf *et al.*, (1965) as

> "a lithologically, structurally or organically distinguishable rock unit detectable in the field".

The facies analysis involves the description and classification of the facies making up any body of sediment followed by the interpretation of the processes and environments of deposition in terms of a facies model. The type of facies model depends on the scale or level of facies analysis (Anderton, 1983). This study includes several scales of facies analysis from the individual bedforms or pedogenic horizons (centimetre scale), through cliff section documentation of channels (decametre scale) to three-dimensional analysis of meanderbelts (kilometre scale) and finally regional documentation of alluvial architecture on a scale of 10's of kilometres. Table 2 summarizes the techniques used for each level of facies documentation as well as their main interprative parameters.

The multidimensional facies analysis used in this study is similar to the type of sedimentological studies initiated by Allen (1983) and later described and demonstrated by Miall (1985 and 1988) as "architectural element analysis". In this analysis, two and three dimensional outcrops are dissected into their componant sedimentation units or "elements" (Miall, 1985) at several different scales or

TYPE OF ANALYSIS	REGIONAL-2D	CONTINUOUS TANGENTIAL SECTIONS-2D	CLIFF SECTION EXPOSURES-2D	EXHUMED 3D SANDSTONE EXPOSURES	MICROSTRATIGRAPHIC VERTICAL SECTIONS
APPROXIMATE SCALES OF FIELD MEASUREMENT	26KM x 0,6Km	900m x 10m	200m x 25m	65Km x 3Km x 0,01Km	20m
TECHNIQUES OF FIELD DOCUMENTATION OF FACIES AND FACIES SEQUENCES	1. Photogeological interpretation of stereoscopic aerial photography 2. Series of parallel transects through escarpment	1. Continuously recorded graphic logs along stream bed and bank exposures	1. Bounding surfaces sketched from sequential photographs 2. Detailed vertical sections measured every 25m along cliff face	1. Photogeological interpretation of large scale aerial photographs 2. Field mapping of sandstone surface using beaconed grid system for positional control 3. Cliff section logging of selected exposures	1. Graphic columnar logs of overbank sequences containing stacked palaeosols measured to 5cm accuracy
MAIN INTERPRETIVE PARAMETERS	1. 1st Order cycles 2. Sandstone to shale ratios 3. Sandstone geometries, "stacking" and connectedness 4. Regional basin dynamics	1. 2nd Order cycles 2. Channel facies associations 3. Interchannel facies associations	1. Architectural element analysis of sandstones 2. Lateral facies relationships of channel and floodplain sequences 3. Palaeoenvironmental analysis of floodplain sequences	1. Palaeochannel morphology and migration behaviour 2. Quantitative palaeohydraulics of trunk channels	1. Sedimentation of floodplain deposits and their pedogenic modification 2. Floodplain accretion rates, palaeotopography and palaeoclimates 3. 3rd Order cycles

TABLE 2 Scales, techniques and interpretive parameters of the facies analyses used in this study

hierarchies separated by different orders of bounding surfaces (Allen, 1983; Miall, 1988). Miall (1985) describes eight basic elements, one or more of which are common to *all* rivers. These include channels, gravel bars and bedforms, sandy bedforms, cross-bedded compound bars, lateral accretion deposits, sediment gravity flow deposits, laminated sand sheets and overbank fines. He promotes the use of this method of analysis which avoids preconceptions about channel morphology and fluvial style by encouraging the user to make a locally developed palaeoenvironmental summary.

The facies nomenclature used in this study is interpretative, summarizing the environment of deposition of a certain rock unit. Facies that consistently occur in juxtaposition or close association with each other are grouped under a larger scale interpretative epithet as "facies associations". Smaller scale features within the facies may warrant recognition as discrete "sub-facies" which are also given an interpretative epithet. The hierachy of interpretative facies nomenclature used in this study is given in Table 3.

Individual facies interpretations are based on available lithological, palaeontological and sedimentological evidence of the rock unit itself, although not excluding the fact that the unit is part of an uninterrupted sedimentary sequence. Thus interpretations of successive facies must be supportive of each other within the overall palaeoenvironmental setting. Emphasis is laid on direct deductions of processes of sedimentation from textures and sedimentary structures. Because individual facies have not been lifted out of their field context the descriptions include documentation of the facies sequences in which they occur. There is, therefore, no statistical analysis of facies sequences included in this study.

Previous facies analyses of the Lower Beaufort have adopted an unbalanced facies subdivision between channel and overbank deposits. This is because the channel sandstones contain uranium mineralization as well as a range of visible sedimentary structures that readily lend themselves to facies description. Kubler

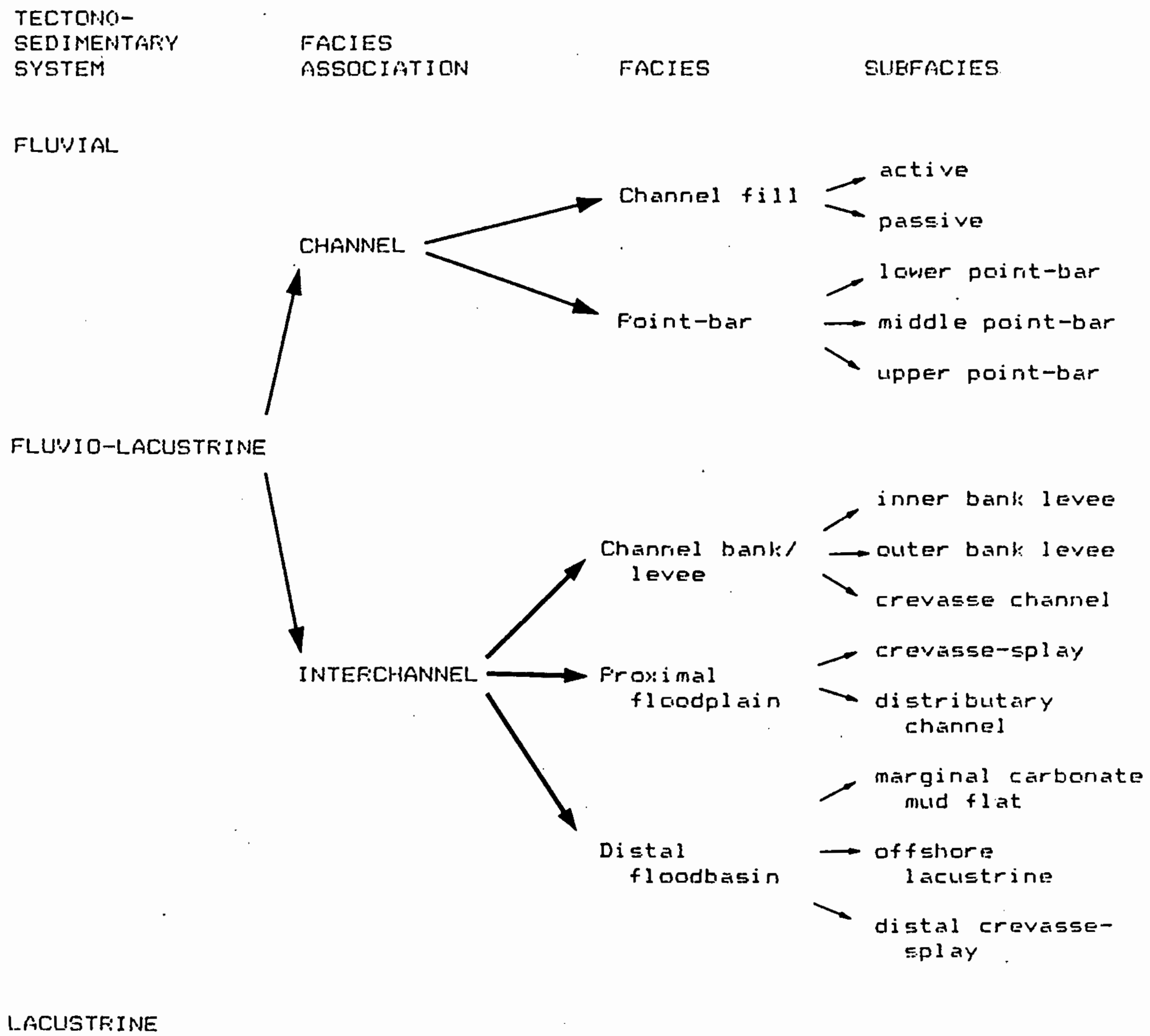


TABLE 3 The hierachy of facies nomenclature used in this study.

(1977) and Cole (1979) both conducted Markov chain-analysis on the Lower Beaufort, the former with five channel sandstone facies and two overbank facies, the latter with nine sandstone to two mudrock lithofacies. In both field areas the ratio of sandstone to mudrock is between 1:4 and 1:6.

One of the aims of the present facies analysis is to present a more well-balanced facies distribution between the channel sandstone bodies and the much thicker intervals of floodplain fines.

2.2. CHANNEL FACIES ASSOCIATION

Within the study areas there are many laterally continuous sandstone outcrops ranging in thickness from 3 m - 20 m (see Appendix maps 1, 2 and 3). All are essentially fine-grained but display a range of geometries and a variety of internal structures. The association of sedimentary facies within these thicker, laterally continuous sandstone bodies is attributed to the transport and deposition of sediment by a confined, unidirectional, channelized flow. The sandstone bodies are enveloped in voluminous mudrocks, the bulk of which were deposited by unconfined flow upon a flat floodplain surface and are collectively grouped into the interchannel facies association.

The sandstone bodies that make up the channel facies association are the preserved coarse fraction of sediments laid down within the confines of ancient meandering rivers and have the following diagnostic characteristics -

1. A sharp basal contact, usually erosional, overlain by sandstone and sometimes intraformationally derived conglomerate.

2. A >2 m thick sandstone body with very minor mudrock layers, displaying a suite of structures reflecting its deposition in a unidirectional water current of fluctuating velocity.

3. An irregular upward transition of sandstone intercalations and textural gradations into the overlying mudrocks.

The channel sandstones in the study areas can be divided into two architectural types based on their gross geometry. The distinction is made primarily on the presence or absence of extensive internal erosion surfaces which are equivalent to the 4th order bounding surfaces of Miall (1988) and are readily observed in cliff sections.

Channel sandstones that range from 4 m to 8 m thick are commonly "single storied" and of simple sandstone geometry containing no extensive internal discontinuity surfaces. Larger sandstone bodies, ranging from 10 to 25 metres in thickness, are invariably of "multistoried" or compound geometry made up of 2 to 4 erosively contacted simple channel sandstones "stacked" on top of each other. Although this is an obvious criterion for defining these two architectural types as different facies, as has been done in the past (Smith, 1980), it is regarded as a reflection of channel behaviour rather than a significant difference in depositional style and, as such, this distinction is not regarded as appropriate for the present facies breakdown. Nevertheless, the following description of channel facies includes field examples from both simple and compound channel sandstones.

The locations of planimetric exposures of channel sandstones in the study area are shown in Figure 1. Two of these, the Reiersvlei and Leeukloof sandstones have been documented in detail as three-dimensional examples of the channel facies association. A continuous two dimensional cliff section exposure through a multistoried channel sandstone, the Waterval sandstone, was documented previously (Smith, 1981) and is presented here both as an example of this architectural type and as an illustration of the complex nature of the upper transition from channel into interchannel sequences.

The extent of the Reiersvlei and Leeukloof planimetric exposures is shown on the geological map of the Reiersvlei study area (Appendix Fig. 1). Although these exposures are now separate, they lie on the same stratigraphic horizon on adjoining farms and are so similar in composition and structure that they may be confidently regarded as having originally been part of the same palaeomeanderbelt. For ease of reference, both these outcrops are called the Reiersvlei Sandstone.

The channel sandstones of the study area are made up of two sedimentary facies which are interpreted as having accumulated within the confines of a meanderbelt as laterally accreted point-bar deposits and vertically accreted channel-fill deposits respectively.

2.2.1. Point-bar Deposits

The Reiersvlei Sandstone is a single-storied, sheetlike sandstone body (by the definitions of Friend (1983) and Bridge (1985)), the bulk of which accumulated on the inner bank of a migrating river meander as point-bar deposits, the remainder accumulating during and after abandonment as channel-fill. Figures 8 and 9 contain photogeological interpretations of two portions of the Reiersvlei Sandstone showing the accretion topography of nine consecutive point-bars which are clearly and continuously separated by the abandoned channel-fill deposits.

The point-bar deposits are composed of fine-grained to medium-grained, moderately sorted, arkosic wacke with carbonate cement. In plan, they form crescent-shaped sandstone bodies covered with an irregular pattern of concentrically disposed "accretionary ridges" (Edwards *et al.*, 1983) that tend to converge on the downcurrent portions of the point-bars and become progressively more splayed toward the meander apices (see Figs. 8 and 9). On the eroded surfaces these "accretion ridges" are low-relief (0.5 m) linear outcrops of thinly bedded, bioturbated, dirty, fine-grained sandstone (Fig. 10) with intercalated maroon and grey burrowed siltstone. The sandstone beds, being more resistant, outcrop for several 10's of metres along a curved strike, dipping gently (16 - 20 degrees) toward the adjacent channel-fill. Palaeocurrent directions taken from the abundant rib and furrow structures in these eroded accretion

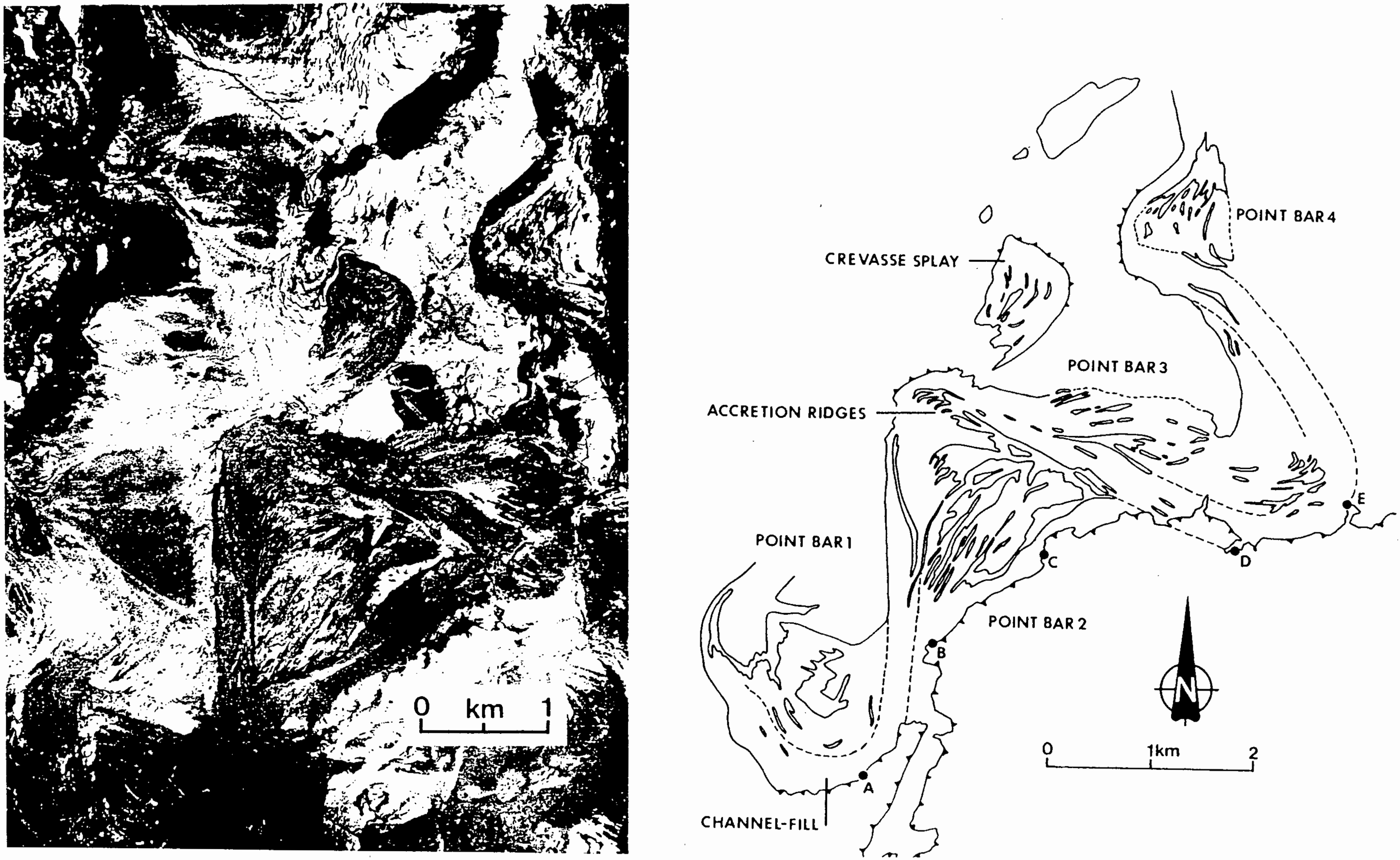


FIG. 8 Vertical aerial photograph and photo-interpretation of the Reiersvlei Sandstone on Ryers Valley 401 and Waterfall 398 (See Fig. 1) showing four consecutive point-bar surfaces with "accretion ridges", abandoned channel-fill and crevasse-splay. The orientation of the crevasse-splay relative to point-bar 2 implies a north-easterly palaeoflow which is confirmed by the palaeocurrent readings.

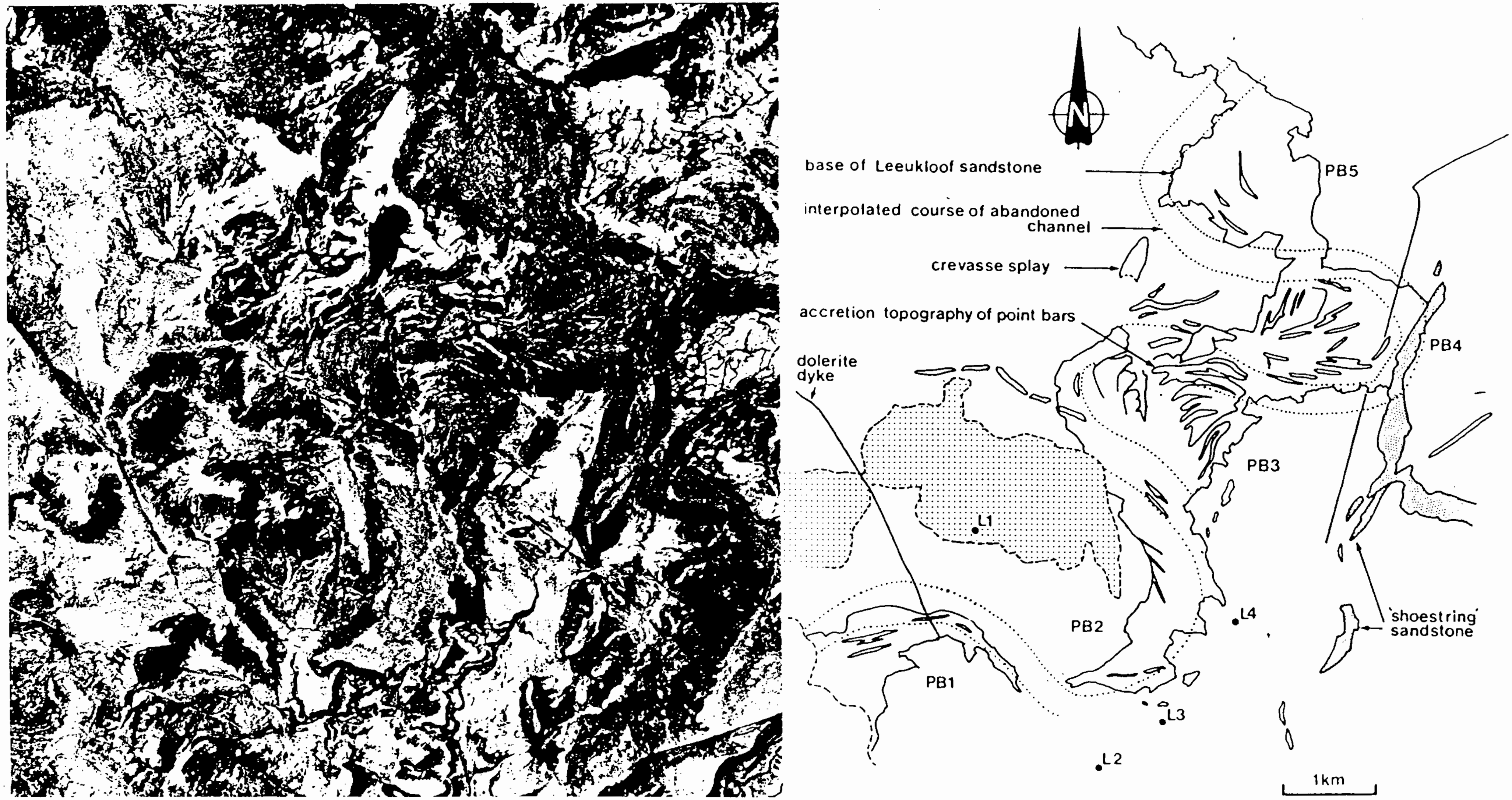


FIG. 9 Vertical aerial photograph and photo-interpretation of the Reiersvlei Sandstone on Leeukloof 402 (See Fig. 1) showing the point-bars of five consecutive meanders and associated crevasse lobes. Narrow "shoestring" sandstones of former distributary channels that have been exhumed from the interchannel deposits are also visible on this farm.

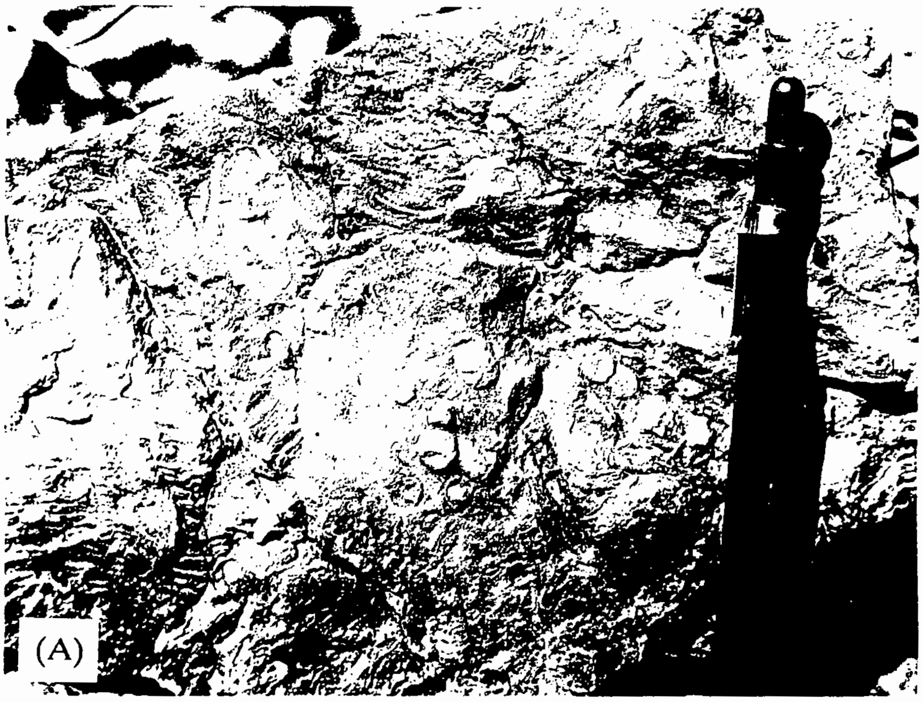
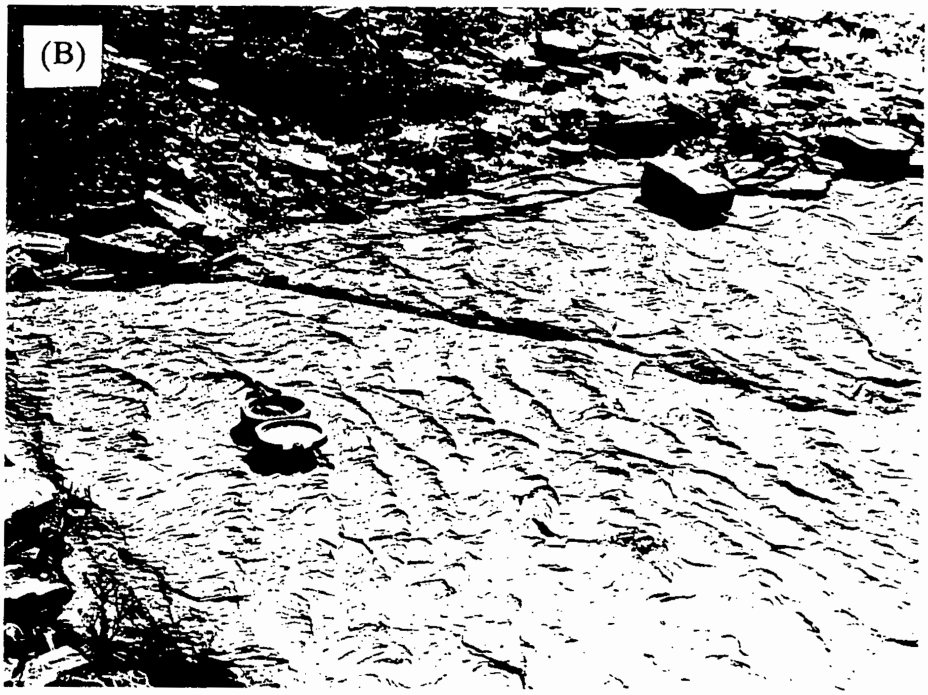


FIG. 10 (A) Bioturbated, ripple cross-laminated, "muddy" sandstone capping one of the "accretion ridges" on the Reiersvlei Sandstone.



(B) Denuded sinuous-crested ripple lamination ("rib and furrow") structures, the most common palaeocurrent indicator on the Reiersvlei point-bars.

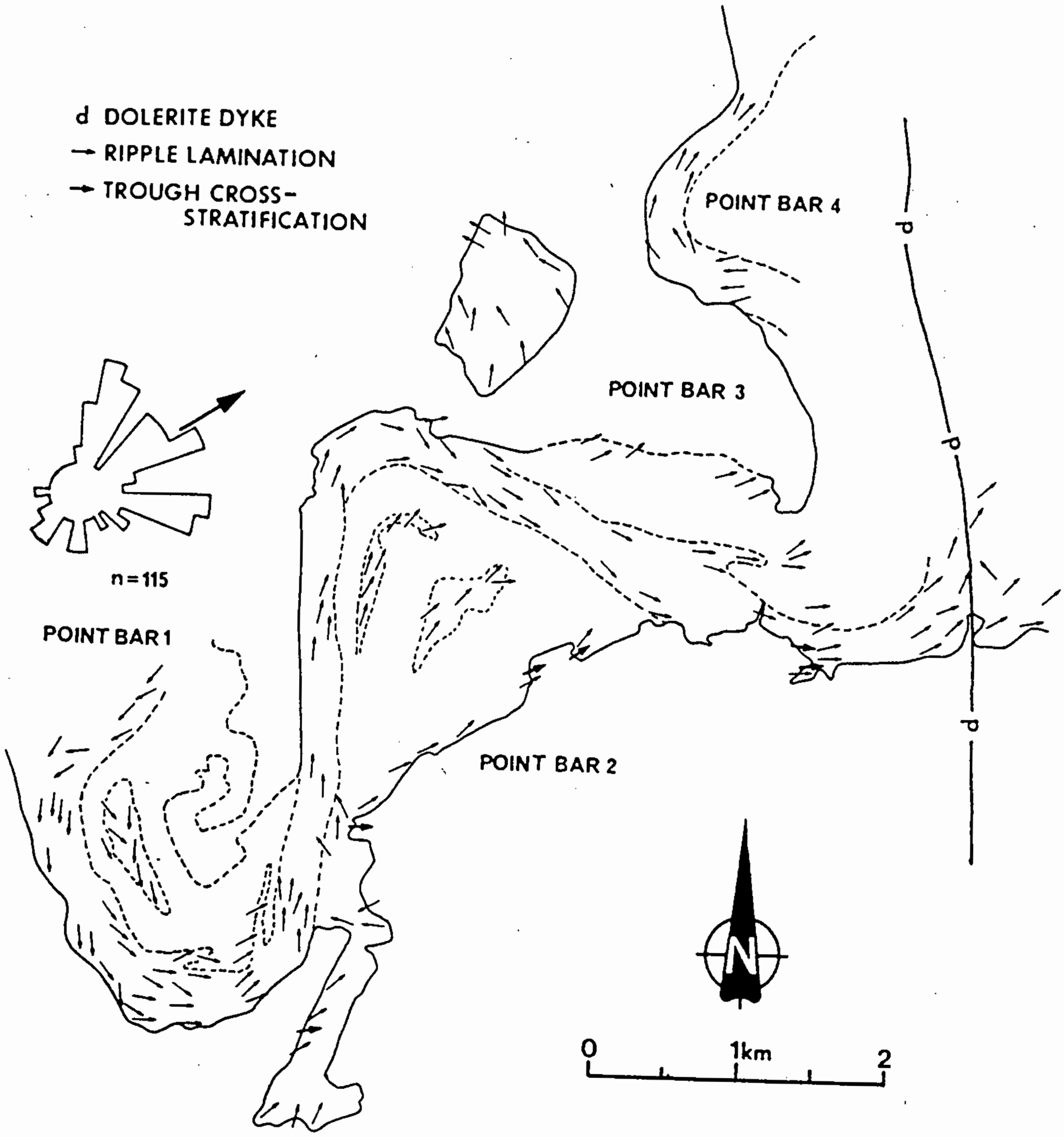


FIG. 11 Palaeocurrent analysis of the Reiersvlei sandstone on Ryers Valley/Waterfall. Solid lines represent sandstone scarps, dotted lines delimit low mounds. The rose diagram, summarizing palaeocurrent measurements of the entire outcrop (excluding crevasse-splay), shows a vector mean of 058 degrees.

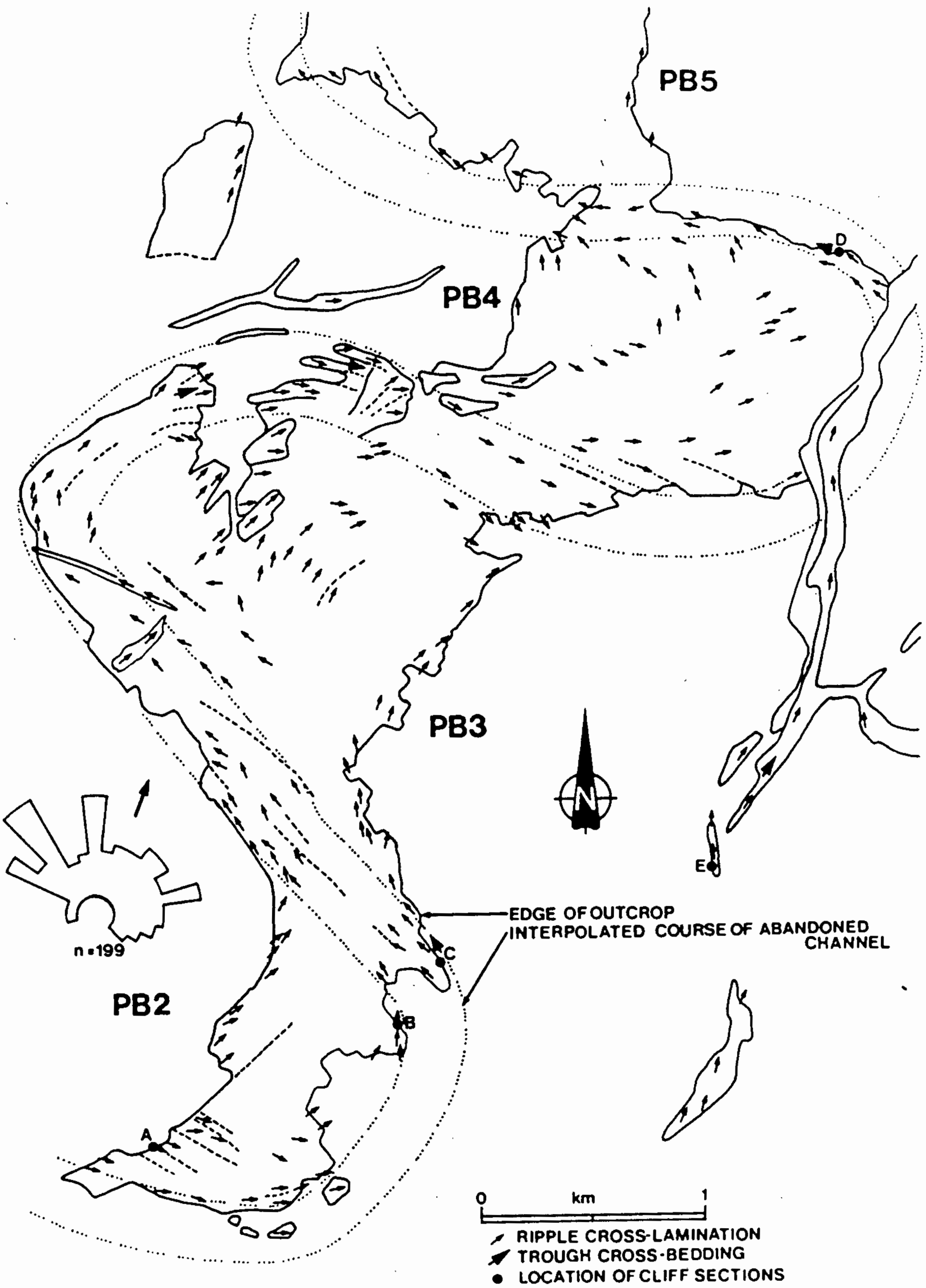


FIG. 12 Palaeocurrent analysis of the Reiersvlei Sandstone on Leeukloof. The rose diagram, summarizing palaeocurrent measurements of the entire outcrop (excluding crevasse-splay and "shoestring" sandstones) gives a vector mean of 024 degrees.

ridges closely follow the strike of the outcrop, although in places, especially at the apex of point-bars, there is an "obliquity" (Edwards *et al.*, 1983) of up to 36 degrees (see Reiersvlei point-bars 1 and 2 of Fig. 11 and Leeukloof point-bars 3 and 4 of Fig. 12).

Measured vertical and cliff sections through the remnant point-bar coarse-member on Leeukloof (Fig. 13a and b) and Reiersvlei (Fig 14b and c) show the generalized upward transitions from a basal scour surface to intraformational mudrock pebble conglomerate to medium-scale trough cross-bedded sandstone to ripple cross-laminated sandstone (often climbing) grading into, and out of, horizontally laminated or structureless, fine-grained sandstone. The upper parts of the Reiersvlei sandstone appears to have been locally re-worked, as shown by the erosively-based trough cross-bedded units occurring at the top of both sections on Reiersvlei. The nature and localization of this reworking suggests contemporaneous chute-channel activity although post-burial erosion by a small "shoestring" channel in the overlying floodplain deposits as on Leeukloof PB4 (Fig. 9) may have been responsible.

The basal erosion surface of the point-bar deposits is generally flat with isolated shallow troughs and "runnels" up to 0.5 m deep (Leeukloof section A of Fig. 14) which are often filled with intraformational mudrock pebble conglomerate. The conglomerates form a 10 - 50 cm thick discontinuous sheet over the erosion surface and are generally clast-supported becoming matrix-supported only at the upward transition into trough cross-bedded sandstone where rip-up clasts are common. Intraclasts composed of oblate mudrock pebbles (up to 10 cm longest diam.), brecciated mudrock flakes, small calcareous glaebules of pedogenic origin and isolated abraded bone fragments are set in a matrix of dirty, medium-grained sandstone. This matrix material also occurs as pebble free, plane-bedded biconvex lenses above, below, and within the conglomerate layers. No extraneous clasts have been recorded in the study areas.

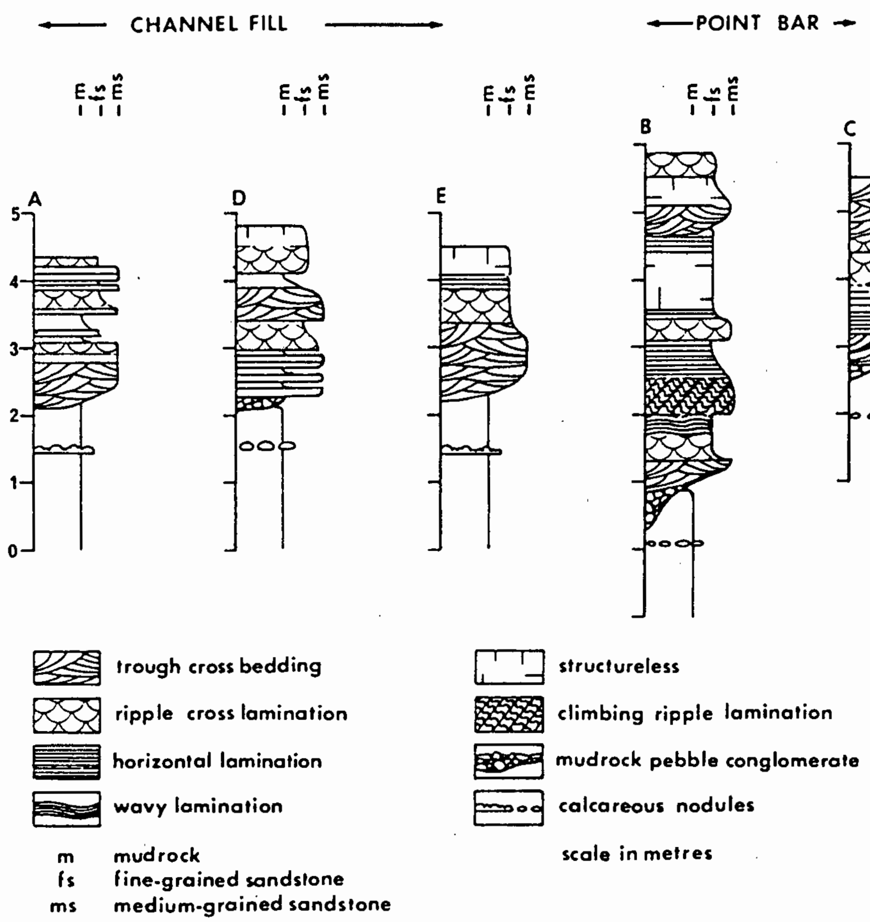
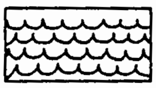


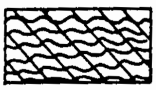
FIG. 13 Graphic logs of 5 vertical sections through the Reiersvlei Sandstone. Localities A-E are shown in figure 8.

LEGEND TO LEEUKLOOF CLIFF SECTIONS

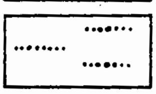

TROUGH CROSS-BEDDING

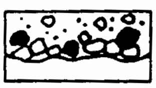

HORIZONTAL LAMINATION WITH SOME LOW ANGLE INTERSECTIONS

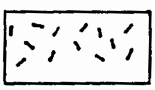

SMALL CURRENT RIPPLE CROSS-STRATIFICATION

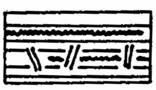

IN-DRIFT RIPPLE CROSS-STRATIFICATION


IN-PHASE RIPPLE CROSS-STRATIFICATION


STRUCTURELESS SANDSTONE


CLAST-AND MATRIX-SUPPORTED MUDROCK PEBBLE CONGLOMERATE. SHADED CLASTS ARE PEDOGENIC NODULES


ISOLATED MUDROCK CLASTS


HORIZONTALLY-BEDDED SANDSTONE WITH NUMEROUS SILTY PARTINGS AND BURROWS

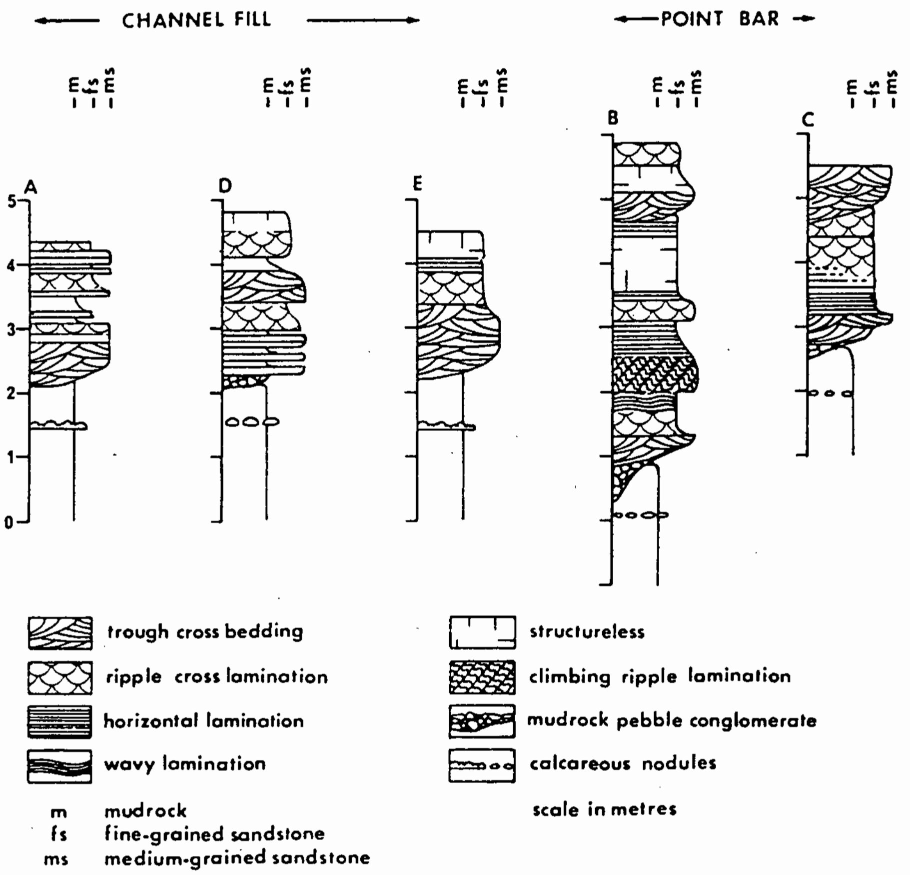


FIG. 13 Graphic logs of 5 vertical sections through the Reiersvlei Sandstone. Localities A-E are shown in figure 8.

LEEUKLOOF CLIFF SECTIONS

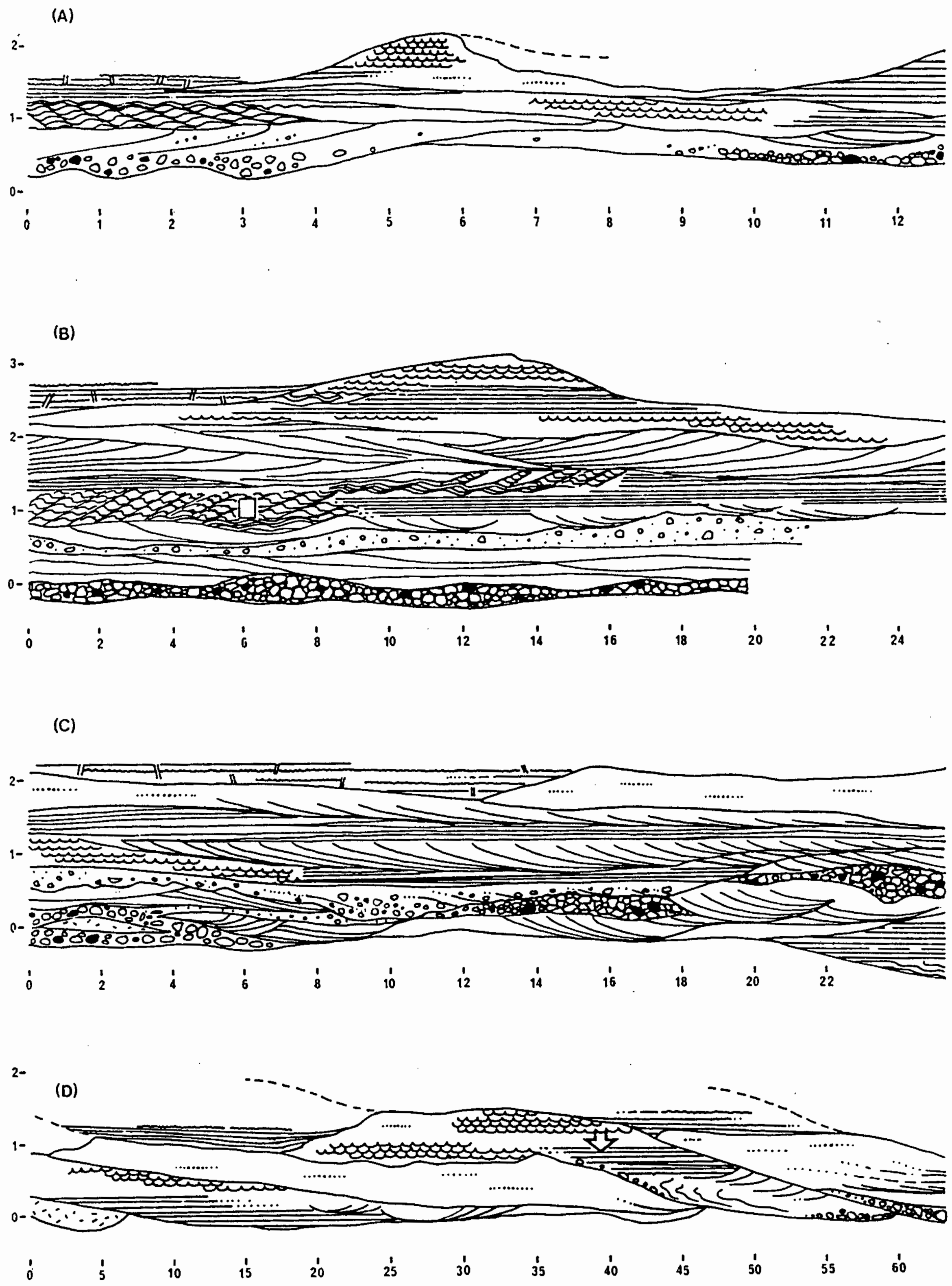


FIG. 14 Four panel sections of cliff exposures of the Reiersvlei Sandstone on Leeukloof. Localities A-D are shown in figure 12. The box in section B shows the position of figure 17 and the arrow in section D indicates the position of figure 16. Scales in metres.

Medium-scale troughs in the overlying unit are wide (3 - 10 m) and shallow (0.3 - 1 m) and up to 30 m long. Most commonly, their preserved width/depth ratios are between 8:1 and 10:1 and width/length ratios range from 1:3 - 1:4.5. They are filled with coarsely-laminated, medium-grained sandstone in concave foresets inclined at their steepest between 15 and 25 degrees. The arcuate bedding planes are commonly plastered with disseminated carbonaceous fragments, scattered mudrock pebbles and/or a single layer of mudrock chip breccia. This imparts a distinctive "flaggy" outcrop pattern in cliff sections that highlights the trough-cross bedding (Fig. 15). The 2 - 5 mm thick laminae within the arcuate foreset units are imparted by a generally "dirtier" purple-coloured sandstone alternating with "cleaner" buff-coloured sandstone. The laminae are composed of imbricated platey carbonaceous and micaceous fragments and a relatively higher concentration of opaque heavy minerals (e.g. magnetite). Most of the troughs have been truncated to form erosively-bound stacked sets up to 1 m thick. These sets grade laterally and vertically into horizontally laminated and climbing-ripple cross-laminated fine-grained sandstone (see Fig. 13b). Horizontally laminated sandstone is compositionally similar to the trough cross-bedded sandstone with laminae defined in the same manner. Bedding planes are commonly clear of mudrock pebbles although in the isolated instances that they do occur, current crescents are often formed around them, thus providing a readily recordable current azimuth for the ubiquitous parting lineation (Fig. 16).

Ripple and ripple-drift cross-laminated sandstone is a common sedimentary unit within the middle to upper parts of the preserved coarse member of the point-bar deposits. In fresh outcrops it is possible to trace individual laminae from horizontal into an in-drift ripple trend (Fig. 17) and back into horizontal again (eg. Fig 13a, b and Fig. 14b). The angle of climb of these ripples increases gradually from the horizontal to approximately 30 degrees before flattening out rapidly or being truncated by the base of the succeeding beds. The gross geometry of the ripple and climbing-ripple units in the mid and upper outcrop (eg. Fig. 13b) appears to define single asymmetrical bar forms up to 1 m high and 5 m wide by 20 m long with arcuate crests orientated perpendicular to palaeoflow. Their position and orientation within the point-bar deposits suggests that they may represent preserved scroll-bars.

FIG. 15 General view of a Reiersvlei Sandstone cliff section showing a thick trough-cross bedded unit at the base.

FIG. 16 Close-up of a current crescent in horizontally laminated sandstone from Leeukloof section D (see Fig. 14). Shallow, high-velocity laminar flow from the top towards the bottom was interrupted by an embedded mud pebble that caused local turbulence and scouring of the sand bed around the pebble and deposition of a "tail" on its leeward side.

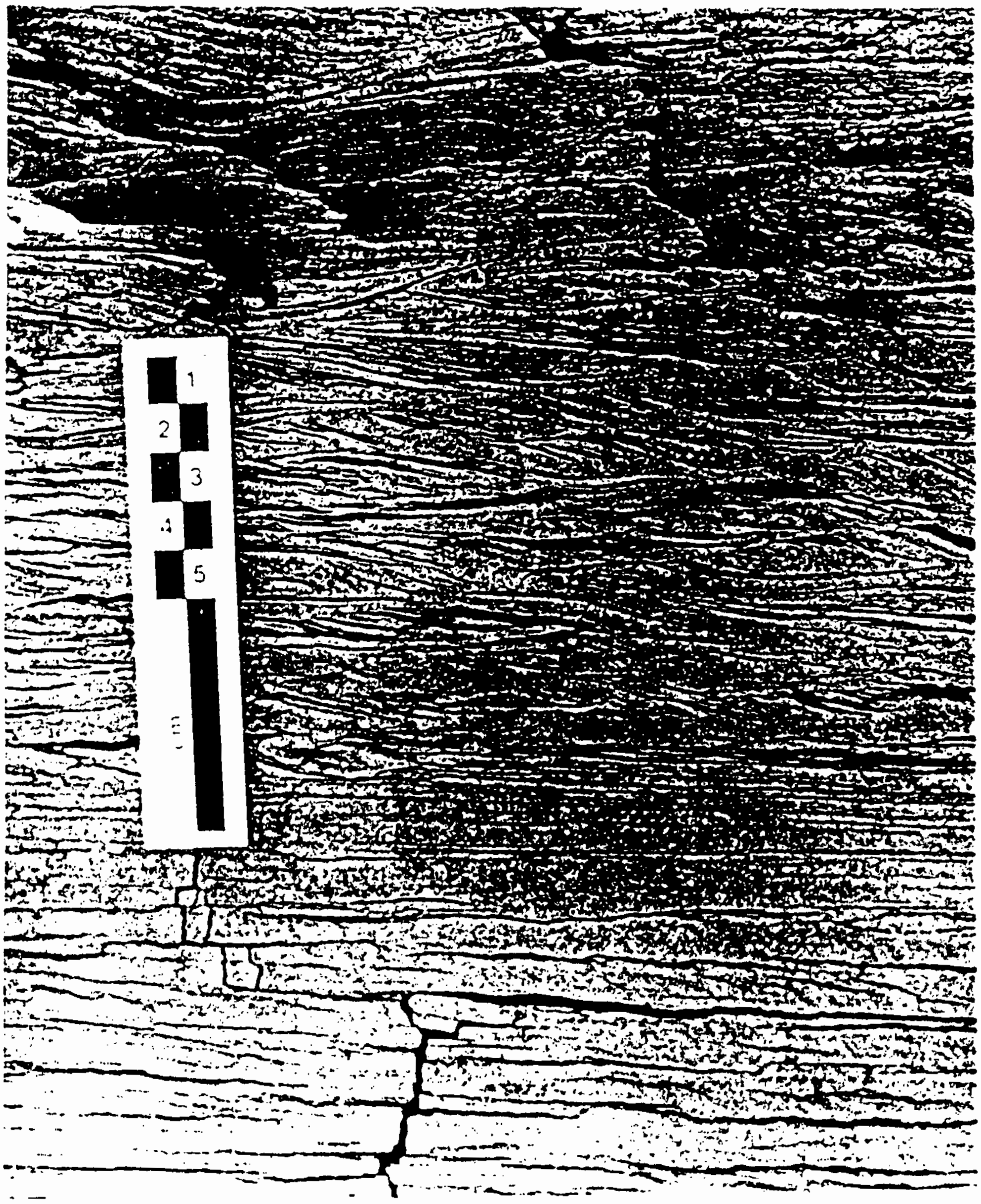


FIG. 17 Horizontally-laminated sandstone passing upward into ripple drift cross-laminated sandstone. These are common sedimentary structures in the mid point-bar sequences. This example was taken from Leeukloof cliff section B (see Fig. 14).

The upper part of the point-bar coarse member is composed of several beds of horizontally laminated, ripple cross-laminated and structureless fine-grained sandstone (Fig. 13a, b). Unfortunately, due to their inter-digitation with overlying mudrocks, these beds are rarely exhumed intact. For this reason they are best studied in steep cliff sections on valley walls such as the Waterval sandstone (Fig. 18 and Appendix Fig. 5) and in fresh stream bed exposures (Appendix Fig. 6).

A detail of the exposure at metre 1700 (see Appendix Fig. 6) of the Leeu River stream bed transect is shown in Figure 19. The flanks of three point-bar ridges and intervening swales display rippled surfaces. Straight, sinuous-crested, double-crested, planed-off and interference ripples are all found on these surfaces. At this exposure the ridge crests and the sandstone surfaces beneath the swale-fills are generally smooth. One of the swale floor surfaces displays numerous sand volcanoes of various diameters but all of approximately the same height (Figs. 20 and 21). Some invertebrate trails have been obliterated by the extruded sand whilst others travel over them. All the volcanoes on this surface have been gently scoured by a 1 cm deep unidirectional sheet flow forming distinctive terracettes and downstream "tails" of sand.

The upper point-bar deposits are transitional both lithologically and sedimentologically with the overlying channel bank/levee deposits making the demarcation of an exact boundary fairly arbitrary. They are characterized by a series of sandstone wedges that "peel-off" the top of the main sandstone body (Fig. 18) at angles of between 10 and 30 degrees into top-stratum mudrocks. The thin sandstone beds have a sharp upper contact but often have a poorly-defined gradational basal contact with the intervening siltstone. In this respect they may be regarded as small (+/- 1 m) coarsening-upward sequences. (Appendix Fig. 5, Fig. 19). Palaeosurfaces are preserved on the upper contact of these sandstone wedges displaying an array of sedimentary and biogenic structures including straight and sinous-crested small current ripples, sand-filled desiccation cracks and, more rarely, run-off rills with numerous vertical and horizontal worm burrows (*Planolites* sp.) similar to those observed in the "accretion ridges" on top of the Reiersvlei sandstone (Fig. 10).

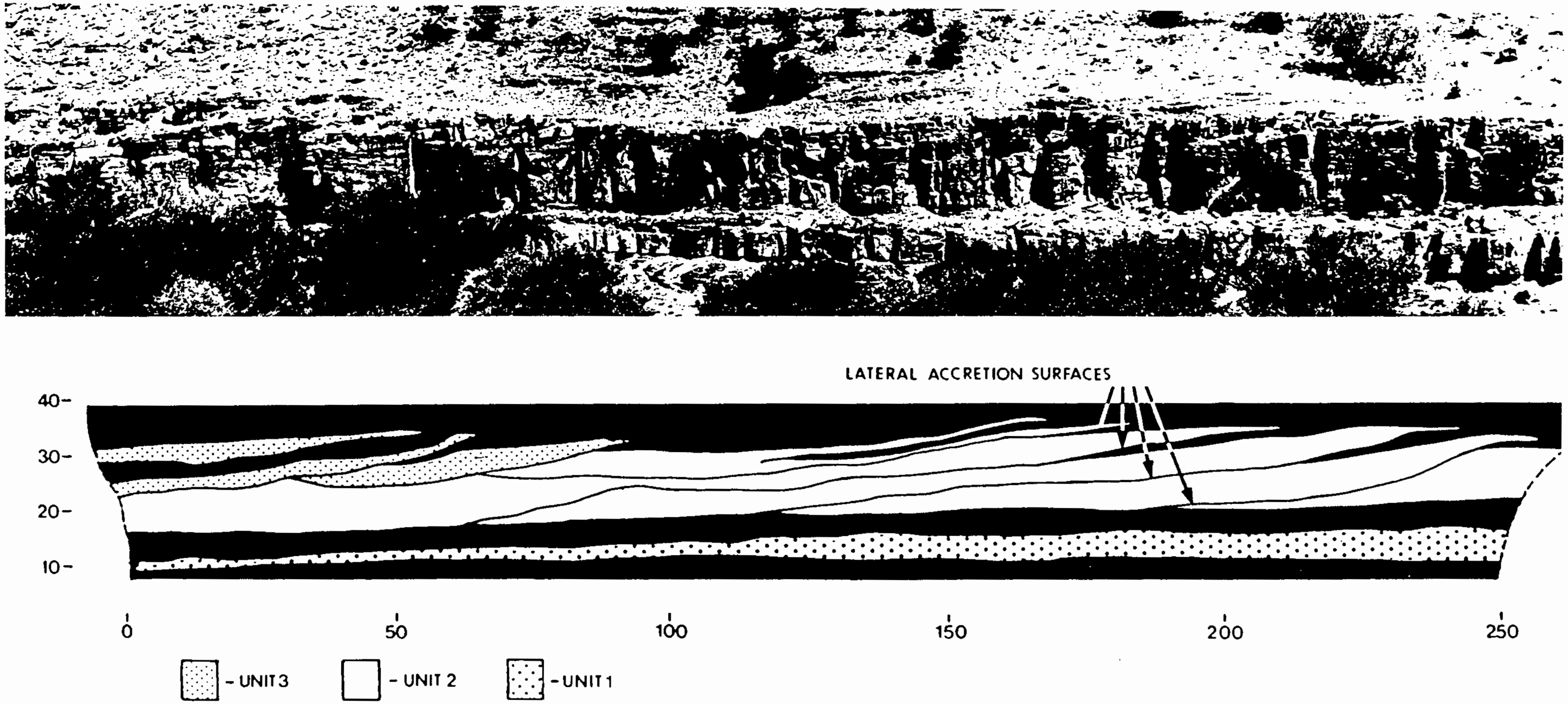


FIG. 18 Cliff section of Waterval sandstone (section E-F of Appendix Fig. 5B), a multistoried high sinuosity channel sandstone. From the top of the offlapping portion of unit 2 (unaffected by the re-working of unit 3), several thin sandstone wedges interdigitate at relatively high angles with top-stratum mudrocks. The bases of these thin beds are continuous with low-angle lateral accretion discontinuities that extend to the base of the coarse member. It is the eroded "stubs" of these sandstone wedges that impart the "accretion ridge" topography to the surface of the Reiersvlei sandstone. Scales in metres.

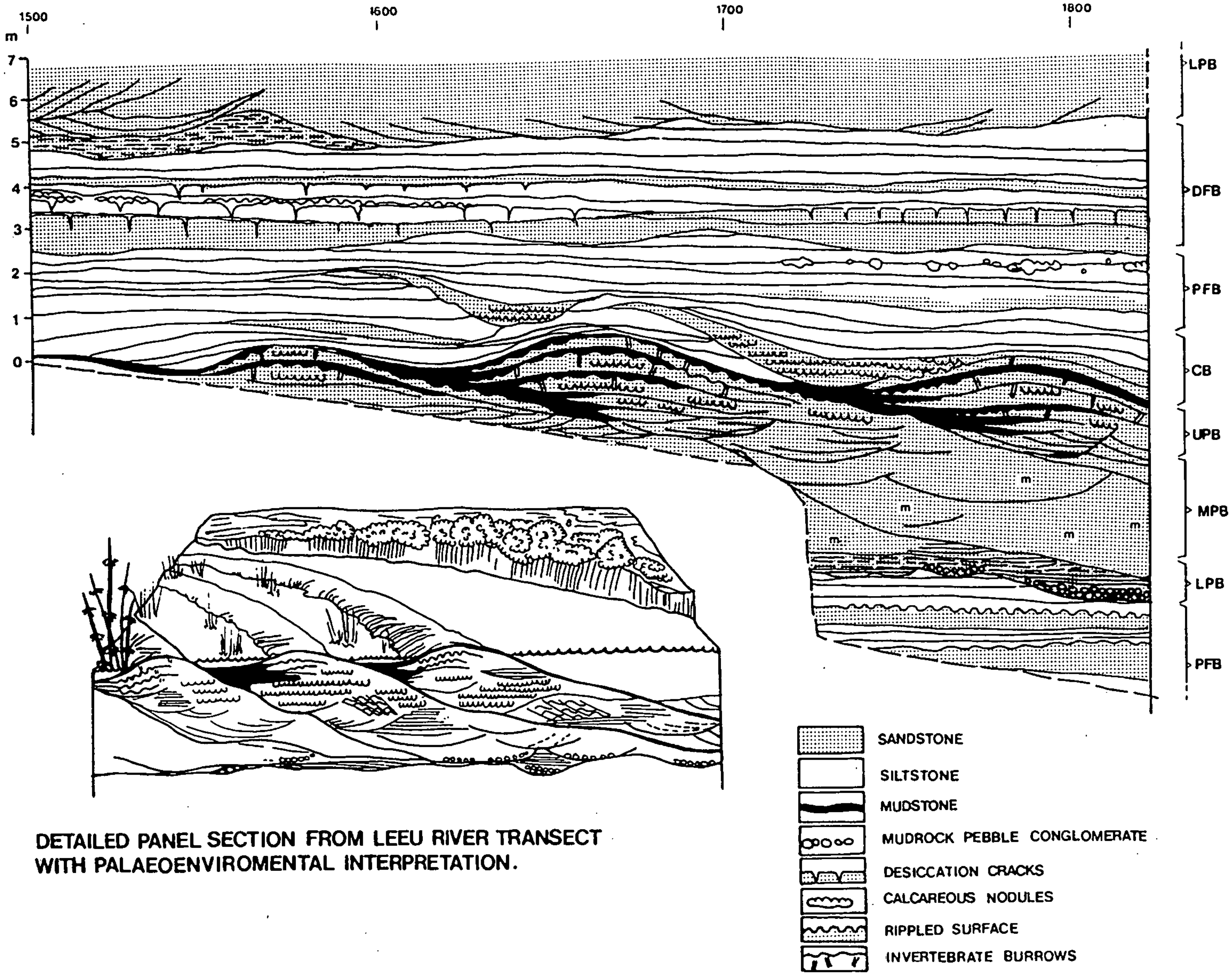


FIG. 19 Detail from metre 1 500 - 1 800 of the Leeu River transect, shown in Appendix Fig. 6, with a palaeoenvironmental interpretation. PFB = Proximal floodbasin deposits, LPB = Lower point-bar, MPB = Mid point-bar, UPB = Upper point-bar, CB = Channel bank, DFB = Distal floodbasin.

FIG. 20 Reworked sand volcanoes on a swale floor exposed in the Leeu River bed at metre 1,700 showing downstream projecting "tails".

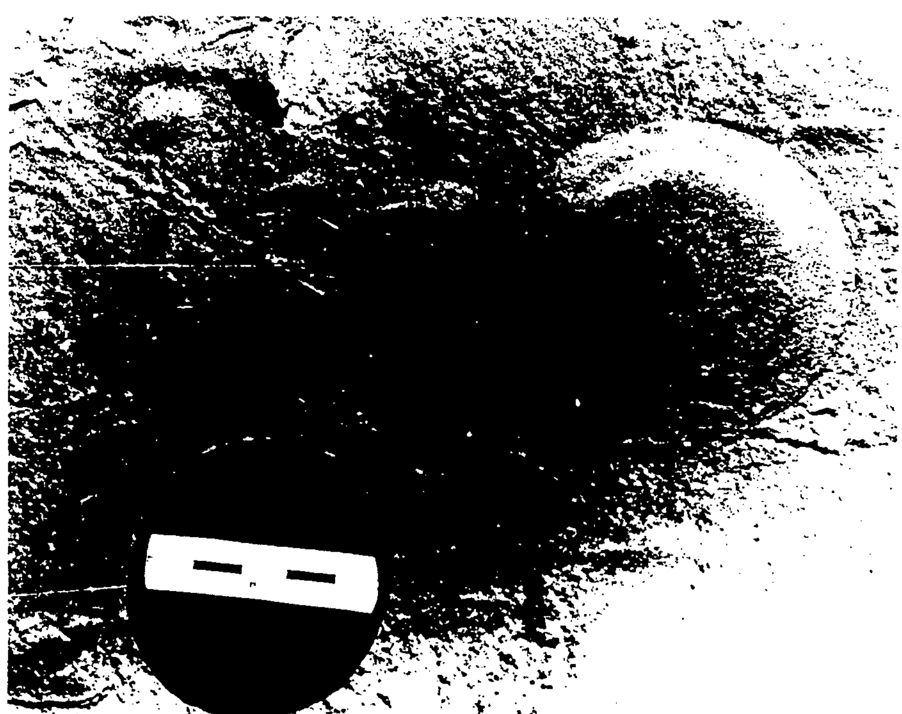


FIG. 21 Close-up of a sand volcano showing the terracette and tail caused by reworking in a 1 cm deep unidirectional sheet flow from right to left. Scale in cm.

The Waterval cliff section exposure (Fig. 18) clearly shows the upper contact of these sandstone wedges to be continuous with inclined scour surfaces that extend at a fairly low angle through the point-bar sandstone to the basal erosion surface. These are interpreted as lateral accretion surfaces representing hiatuses in point-bar sedimentation. Similar surfaces are documented in the Reiersvlei sandstone cliff sections (eg. Fig. 13a, b) where they dissect the sandstone body at an angle of approximately 10 degrees and can be traced over a distance of up 225 m. In this case the "peeled-off" sandstone inter-digitations with the overbank mudrocks have been severely denuded leaving only the eroded stubs as remnant accretion ridges. The outcrop between accretion ridges is mostly obscured by recent alluvium but in cliff section exposures this material can be seen to comprise a distinctive horizontally laminated "dirty" sandstone with numerous vertical burrows (see Fig. 13a, b), silty partings and mudcracks. In stream bed exposures along the Leeu River similar sequences, exposed in fresh outcrops, show complicated upward and lateral relationships that are summarized in Figure 19.

It is concluded, from field evidence, that the "accretion ridges" on the upper surface of the Reiersvlei sandstone are associated with lateral accretion surfaces but do not depict more than a very eroded remnant of the original point-bar ridges.

A very similar sequence of point-bar deposits displaying much more steeply dipping lateral accretion surfaces (inclined stratification of Thomas *et al.* 1987) is shown in the Dunedin cliff section of Appendix Figure 6. The main difference between the Dunedin and Reiersvlei fluvial systems was one of scale: the Dunedin channels were considerably narrower and shallower and may be regarded as a smaller 2nd order drainage system that flanked the major meanderbelts.

2.2.2. Channel-fill Deposits

On the Reiersvlei sandstone surface channel-fill deposits form a continuous low mound, approximately 250 m wide by +/- 2 m high, following the curved margin of each point-bar (Figs. 8 and 9). The lower parts of the channel-fill sequences are similar to the lower point-bar deposits. The basal erosion surface has a low profile and is overlain, in places, with clast-supported mudstone pebble conglomerate. These give way vertically and laterally to horizontally-laminated, trough cross-bedded and massive sandstone with isolated ripped-up mudrock clasts. In the centre of section 13c a near-complete longitudinal section through a trough is preserved. It is some 20 m long and 0.5 m deep. In some places (eg. Fig. 14d) the sandstone has become thixotropic resulting in deformed laminae. This process may also be responsible for forming the massive sandstone units.

The upper portion of the channel-fill coarse member is composed of fine-grained sandstone with a "flagstone" outcrop pattern imparted by numerous sharply bounded thin planar beds of ripple cross-laminated sandstone, separated by thin maroon siltstone or mudstone veneers (Fig. 13a, d, e and Fig. 14c, d). Numerous invertebrate burrows vertically penetrate the sandstone layers and laterally exploit the mud-rich laminae.

Around the apex of each meander the lower trough cross-bedded unit becomes thicker and progressively coarser from the concave to convex side, where it forms sharply defined 2 m high scarps (Fig. 22). Cliff sections measured on the meander apices (Fig. 14d, e) are dominated by trough cross-bedded sandstone with only minor "flaggy" sandstone units, whereas the latter dominates the channel-fill of straight stretches (Fig. 14d). Rib and furrow palaeocurrent readings taken along the channel-fill mounds of the Reiersvlei sandstone closely parallel the outcrop margin and clearly demonstrate the original flow patterns (Figs 11 and 12). Along the straight channel stretch between PB2 and PB3 of Figure 14 the channel-fill deposits contain prominent, slightly sinuous ridges of medium-grained massive sandstone resembling mid-channel, longitudinal bar forms.

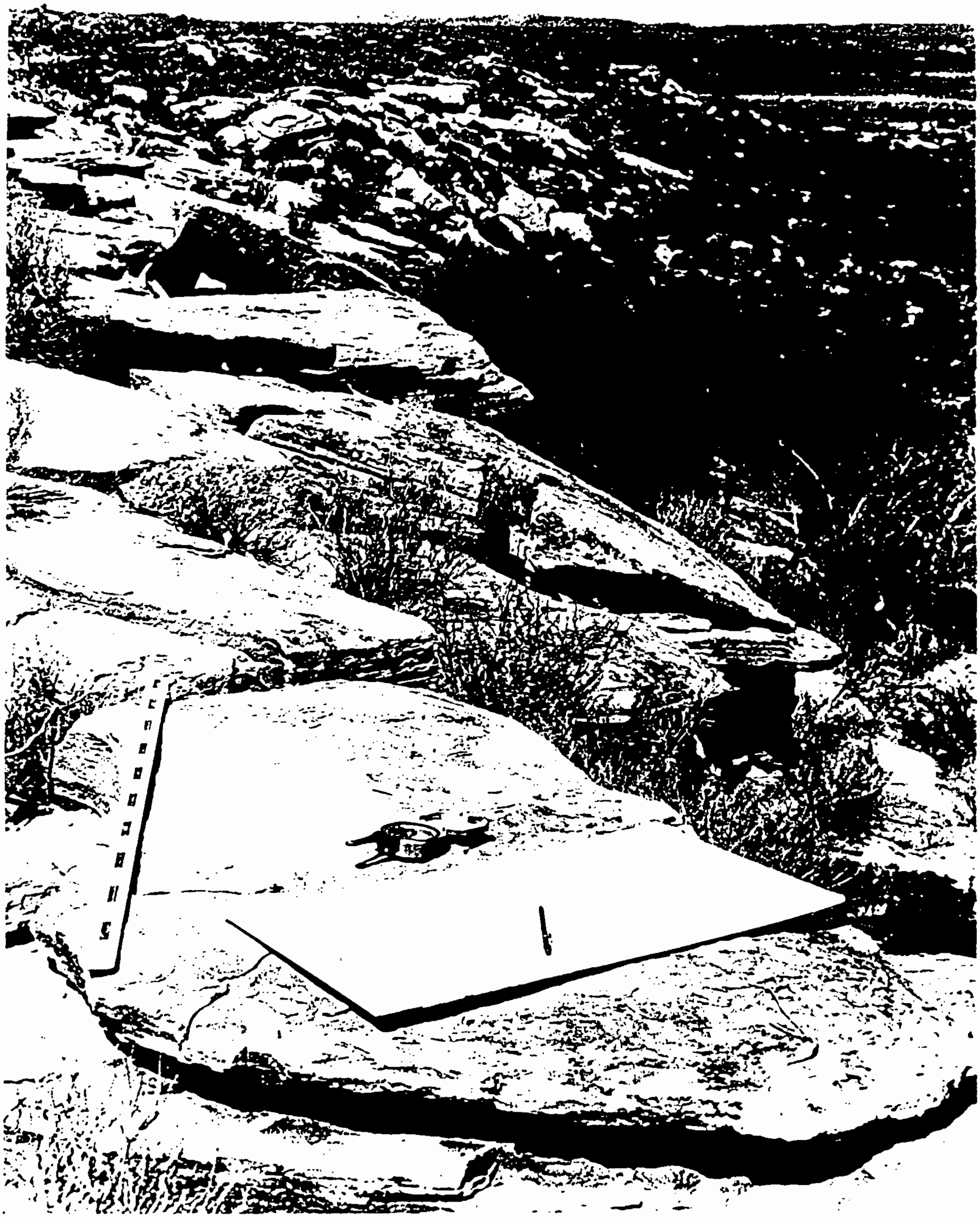


FIG. 22 A view along the exhumed channel-fill deposits that form a low sandstone scarp at the edge of point-bar 3 on Leeukloof (see Fig. 9).

Channel-fill deposits of the Waterval sandstone cliff sections show a similar scale and composition to those of the Reiersvlei sandstone, although large scale conformable channel-fill bedding is in evidence (Appendix Fig. 5). Channel-fill sandstone making up these conformably layered units is predominantly structureless becoming ripple cross-laminated towards the top where rippled surfaces are preserved beneath greenish mudstone veneers. Channel-fill deposits of the lower of the two superimposed channel sandstones that make up the Waterval sandstone end abruptly, with an almost vertical contact, against mudrocks of the interchannel facies association (Appendix Fig. 5). Palaeocurrent readings support the interpretation that this represents the concave cut-bank immediately prior to final abandonment of the meander. Corroborative evidence for this interpretation is the presence of rotationally slumped mudrock blocks in the cut-bank section that are similar to those described by Turnbull *et al.* (1966), Nami and Leeder (1978, p. 434) and Puigdefabregas and Van Vleit (1978, p.475).

Conformable bedding is also a feature of the channel-fill deposits of the Dunedin L1 section (Appendix Fig. 7) although on a much smaller scale (preserved channel widths +/- 50 m). In this outcrop the lateral accretion surfaces in the point-bar deposits are only 50 - 75 m long and dip more steeply (25 - 30 degrees) towards the channel-fill than those of the Waterval and Reiersvlei sandstones.

2.2.3. Hydrodynamic Interpretation of Point-bar and Channel-fill Deposits

Morphological, textural and sedimentological characteristics of both point-bar and channel-fill facies of the channel facies association reflect episodic, flood-dominated sedimentation. Episodic sedimentation is evidenced by the irregular spacing of point-bar accretion ridges on the Reiersvlei sandstone surface as well as the uneven, scoured bases of lateral accretion units ("bundles" of Puigdefabregas, 1973) exposed in the Waterval sections. The continuity of inclined and scoured accretion surfaces that extend to the base of the sandstone unit, is well demonstrated in the Dunedin and Waterval cliff sections. This is interpreted as evidence of large discharge fluctuations (Puidgefabregas, 1973;

Puigdefabregas and Van Vleit, 1978; McCabe, 1978) and possibly periods when flow ceased altogether (Stear, 1980).

Catastrophic overtopping and breaching of the channel banks is clearly evidenced on the Reiersvlei outcrop by the exhumed crevasse-splay sandstones emanating from the apex of meander 2 of Figure 11 and PB3 of Figure 12. This sandstone, which will be described in more detail with the interchannel floodplain facies association, has similar geometry and textural characteristics to modern ephemeral-stream sand sheets described by McKee *et al.* (1967) and Sneh (1983).

Flood dominated sedimentation is also evidenced in the relatively large proportion of horizontally-laminated sandstone and trough cross-bedding in the lateral accretion units. These structures reflect upper flow regime conditions typical of flood stage sedimentation on the lower and middle point-bar (Allen, 1963). The uneven scoured surfaces on which the lateral accretion units accumulated are evidence of the rapid increase in flow velocities, prior to sedimentation, during rising and peak flood stages (Friend *et al.*, 1979; Shepherd, 1987).

The convex surface profile of the larger Reiersvlei point-bars sloped progressively more steeply towards the water's edge from near horizontal on top to approximately 15 degrees at the margins. Smaller meander systems such as the Waterval and Dunedin sandstone had generally steeper "slip-off" slopes of up to 30 degrees.

Individual accretion units are interpreted as having accumulated in the manner described by Jackson (1976b) whereby sinuous-crested bars that normally travel round the bends in the thalweg are, during flood events, "beached" on the downstream side of the point-bar.

The pattern of accretion ridges on the eroded Reiersvlei sandstone surface closely resemble Lewin's (1978, fig. 1) contour map of a modern meander in the Rheidol River in Wales, especially in the convergence of irregularly spaced, gently curved point-bar ridges on the downstream margin of the point-bar as well as the presence of "large elongate linguoid bar forms" on the active channel bed. Preservation of the latter is, according to Lewin (1978), a consequence of "flashy" discharge where normal flow conditions are incapable of significantly modifying peak-flood mid-channel bars. The irregularity of the Reiersvlei accretion ridges, when contrasted with the periodic ridge and swale corrugations figured by Padgett and Ehrlich (1976) and Nami (1976), suggests that the Reiersvlei meanders had a jerky migration behaviour with correspondingly intermittent point-bar accretion.

Purkait (1983) compared sediment-transport directional structures on the surface of modern ephemeral-stream point-bars with water flow directions in the adjacent channel. He found that azimuths of small current-ripple trends on the point-bar surface are nearly parallel to water flow directions in the adjacent channel and, if preserved, would be reliable palaeocurrent indicators. Despite the much larger scale of the Reiersvlei system, the patterns of current directions determined from sinuous-crested ripples (rib and furrow structure) on the Reiersvlei point-bars are closely comparable to those of the Usri river point-bars in India (Purkait, 1983 - his figs. 2a and 2b).

The composition and distribution of mudrock-pebble conglomerates within the lower point-bar and channel-fill deposits is comparable to that of thalweg gravels in many modern meandering river systems eg. Mississippi (Fisk, 1944), Wabash (Jackson, 1976), Beatton (Nanson, 1980) and South Esk (Bridge and Jarvis, 1976, 1982). They are derived from the erosion of semi-consolidated clay-rich alluvium making up the bed and banks of the river channel mainly through the mechanism of undercutting and collapse of the outer bank around, and immediately downstream from, the apex of the meander (Jackson, 1981; Plint, 1986).

The Teekloof channel conglomerates commonly contain consolidated calcareous glaebules (up to 5 cm diameter) that were originally formed in soil profiles on the channel banks and subsequently collapsed into the thalweg. Sarkar (1988) used the presence of reworked unabraded peloids in channel-lag conglomerates as evidence for contemporaneous caliche development in floodplain deposits that had not otherwise been preserved in the succession. In the Teekloof Formation, however, there are abundant similar nodules in the interchannel deposits to substantiate their floodplain origin.

Jackson (1981) recorded the lithological and textural changes in bed sediments around several meanders of a muddy fine-grained river (Little Sugar River) in Winsconsin. Cohesive silt pebbles were shown to accumulate within thalweg scour pools on the river bed, particularly in the thalweg crossovers and near cut-banks. In areas of migrating ripples, the clasts were concentrated into the ripple troughs. The distribution of mudrock conglomerate in the Teekloof sandstones, being mainly confined to erosive troughs in the basal surface, is in accordance with the interpretation that they were locally derived from cut-bank collapse and accumulated in thalweg scour pools on the river bed to be buried initially by migrating sandwaves and eventually by the expanding inner bank point-bar.

The poorly-sorted horizontally-laminated sandstone forming the matrix and clast-free lenses within the conglomerates may have accumulated from a succession of migrating, low-amplitude sandwaves similar to those described by Smith (1971) and McBride *et al.* (1975). Alternatively, they simply represent upper-flow regime plane-bed conditions where laminar flow conditions have winnowed the sandy bed to leave a thin traction carpet of imbricated heavy minerals that now form the "dirty" laminae (Frostick and Reid, 1977).

Current crescents around isolated mudrock pebbles in these plane-bedded sandstones (Fig. 21) support the upper flow regime interpretation. Pebble scours are common in modern flash-flood ephemeral stream deposits (Picard and High, 1973) and Billi and Tacconi (1985) noted that widespread deposits of horizontally-laminated sand with pebble scours is characteristic of flash-flood sedimentation in ephemeral streams of North Somalia.

The distribution of trough cross-bedding in the lower to middle parts of the point-bar sandstone varies with position around the meander. On sections upstream of a bend (Fig.14a) it is less common than on sections downstream of the meander apex (Fig.14b). Within the Reiersvlei channel-fill deposits, troughs are larger and more common on the outer edge of bends (Fig.14c) than on the inner bank (Fig.14d). Large and medium scale trough cross-bedding is interpreted as resulting from the downstream migration of dunes of various wavelengths and amplitudes with lunate (or crescentic) crests (Allen, 1963; Williams, 1968; Coleman, 1969; Jackson, 1976 b). On a sandy streambed, with turbulent boundary conditions, trough cross-strata may result from the burial of large elongate spoon-shaped scours (pool and riffle surfaces) by subaqueous sandwaves (Harms and Fahnestock, 1965). Such troughs may be scoured out by streaming vortices in the thalweg during rising flood stages or by turbulence caused by flow separation in the lee of an advancing dune (Bridge and Jarvis, 1982).

By inference, therefore, it appears that the dunes migrating around the Reiersvlei meanders were larger on the outer channel bed than on the inner side reflecting deeper water depths and increased flow velocities in the thalweg. A similar distribution of bedforms has been documented in Mississippi River point-bars by Hayes (1985). He noted that the water depth was mainly determined by variations in scour and infilling of a channel bed that was made up of several orders of superposed dunes which, in general, increased in size and complexity from inner to outer bank. The inner bend dunes were laterally continuous and sinuous crested, whereas thalweg dunes were larger, solitary and lunate. Such a bedform distribution may well explain the abundant trough cross-bedded sandstone in the lower parts of the point-bar accretion units and channel-fill deposits of the Teekloof channel sandstones.

Ripple and ripple-drift cross-lamination is the commonest structure in the upper parts of the Teekloof point-bar accretion units. It is formed by the migration of ripples under changing velocity/sediment load conditions most commonly associated with rising and waning flood cycles (McKee *et al.*, 1967; Jopling and Walker, 1968; Nanson, 1980). The vertical and lateral gradation of horizontal lamination into sinusoidal (in-phase) and climbing (in-drift) ripple cross-lamination is present in the upper point-bar coarse member of the Reiersvlei, Waterval and Dunedin sandstones. This sequence is often scoured by trough cross-stratification (see Fig. 14b) that passes upwards into horizontally laminated sandstone.

During waning flood, ripples form on the upper parts of the subaqueous point-bar and begin to migrate. Further deceleration of flow leads to increased suspended load sedimentation which causes the ripples to accrete on both lee and stoss sides but continue to migrate thus forming climbing or in-drift ripple cross-laminations. At even slower velocities there is no downstream migration and with continued sedimentation there is complete preservation of both lee and stoss sides to form sinusoidal, in-phase ripple cross-laminae.

At peak flood discharge, the helical vortex of maximum velocity that normally flows on the outside of the bend becomes distorted and may switch to a straighter route across the face of the submerged point-bar (Jackson, 1976a) causing sinuous-crested dunes to migrate over this part of the bed leaving behind a layer of trough cross-bedded sand.

Under a flash-flood hydraulic regime the rapid waning of flow velocities combined with falling water-levels may cause the last sinuous dune forms to be "stranded" in the upper mid-bar position (Jackson, 1976b). The arcuate bar-forms preserved on top of Leeukloof cliff sections 14a and 14b are interpreted as sinuous-crested dunes that became "beached" during bankfull discharge on the upper mid-point-bar. During waning flood, the thalweg reverts back to its normal position on the outside of the meander, leaving the stranded dune surface to be modified by small current ripples. The angle of "obliquity" of the bar form to the prevailing current will determine the direction of these small ripples. Modern studies have shown there to be a tendency for the ripple trends on either side of point-bar ridges to converge on the downstream end (Jackson, 1976b; Dietrich *et al.*, 1979; Nanson, 1980). These have been termed "swept ripples" by Allen (1968) and are interpreted as having given rise to the convergent rib and furrow palaeocurrent directions on some of the arcuate ridges on the Reiersvlei sandstone surface (eg. Fig. 11 PBI).

The prominent lateral accretion bedding displayed by the upper point-bar deposits of the Waterval sandstone is an alternation of sandstone and mudrock lithologies and may be more aptly described as cosets of inclined heterolithic stratification (Thomas, 1987) as opposed to the traditional epsilon cross-stratification of Allen (1965). These beds are interpreted as having accumulated on the upper levels of a point-bar, especially on the downstream side, within slackwater pools or sloughs between sandy point-bar ridges. Figure 19 demonstrates the geometry and sedimentary characteristics of the upper point-bar deposits. Each small (1 m thick) coarsening-upward unit begins above, and terminates at, a sharp non-deposition surface that continues downwards into the lower point-bar sequence. This overall coarsening-upward trend records the upward and bankward building of the sandy point-bar ridge into the intervening slough during successive bankfull flows (Nanson, 1980). The rare occurrence of preserved sand volcanoes on the surface of a slough-base sandstone suggests that organic detritus had collected in these slack-water "ditches" and began to decompose before being rapidly buried with a sand layer introduced during a subsequent flood. This is in accordance with the observation of Fisk (1944) that floating debris was invariably trapped in the swales during waning flood. As the meander migrated these ridges and swales were further removed from the channel and became draped with overbank silts and muds which gradually built up to form natural levees (Fisk, 1944).

A similar sequence of mud-rich lateral accretion units is described by Jackson (1981) from the Little Sugar River in Winsconsin where the basal coarse-member of the point-bar deposits comprise only a quarter of the total thickness of laterally-accreted strata. Thus, it is possible that the Reiersvlei sandstone represents only the more resistant coarse-member of a muddy fine-grained meanderbelt and the upper heterolithic accretion units that have been removed may have been two to three times as thick.

2.3. INTERCHANNEL FACIES ASSOCIATION

At least 80 percent of the Teekloof Formation strata are composed of superficially monotonous successions of drab grey and greenish siltstone with interbedded thin (<3 m) tabular sheets of fine-grained grey to buff-coloured sandstone and minor dark grey or maroon-coloured mudstones. These are the interchannel or overbank mudrocks that host the palaeontological wealth of the succession. They contain the fossilized skeletons of mammal-like reptiles, pareiasaurs and other, rarer anapsid reptiles, and amphibians. Traces of vertebrate activity recorded in the study areas include bone-rich regurgitates, coprolites of both carnivorous and herbivorous origin, natural casts of underground burrows and preserved trackways.

The mudrock intervals contain evidence of pedogenic modification of the alluvium in the numerous horizons of calcareous nodules, rhizocretions and root moulds. The palaeosols are the subject of a more detailed study that is presented later in this report. Other minor lithologies that occur sporadically in these mudrocks include thin discontinuous "chert" lenses and thin green mudstone layers of probable tuffaceous origin. The "chert" lenses contain traction current structures and invertebrate borings suggesting that a single siltstone bed has been preferentially silicified.

Within the study areas, channel sandstone ledges cap fairly continuous exposures of interchannel mudrocks. Most of these cliff sections have been searched for fossils (see Appendix Figs. 19, 20 and 21). Three large clean mudrock exposures were recorded on microstratigraphic panel sections namely Dunedin, Leeukloof and Wilgeboskloof panel sections (Appendix Figs. 7, 8 and 9). Eight others have been logged and recorded in detailed columnar sections (Appendix Figs. 11 to 18). Whilst recording these data, particular attention was paid to vertical and lateral facies relationships as well as to the occurrence and taphonomy of vertebrate fossils and the nature and extent of palaeopedogenesis.

Three distinct overbank or interchannel facies and four subfacies are recognized in the interchannel intervals of the Lower Beaufort (Table 3). These facies are interpreted as having accumulated on the lowland areas between meanderbelt ridges, mainly by the settling-out of fine-grained sediments from floodwaters that periodically spilled over the banks of the main channels. Their distinction is due to a combination of lithologic, sedimentologic, taphonomic and pedogenic differences attributed to their position in the interchannel depository and, in particular, to the distance away from the major meanderbelts.

The lithological and sedimentological characteristics of the interchannel facies and their subfacies are described below. Succeeding chapters include descriptions of the palaeosols and vertebrate taphonomy of these facies.

2.3.1. Channel Bank/Levee Facies

Channel bank deposits comprise 1 - 3 metre thick sequences of sandstone/siltstone couplets or bedsets (Bridge, 1983), each in the order of 5 - 10 cm thick. Extensive internal scour surfaces are a distinguishing feature of these deposits, the geometry of which is used to distinguish between inner-bank levee and outer-bank levee deposits.

The channel bank sequences as a whole follow a general fining-upward trend whereby the siltstone component of the couplets becomes dominant over the sandier portion in the upper parts of the sequence before passing into fissile silty-mudstone beds. Crevasse-splay and crevasse channel deposits commonly truncate the channel bank sequences, especially in outer bank subfacies. Calcareous nodules occur in horizons within these deposits. They are usually smooth surfaced, isolated and oblate and become more common in the upper parts of the sequence. Therapsid fossils are common to abundant in restricted parts of channel bank exposures, otherwise they are generally rare.

The inner- and outer-bank deposits are lithologically similar. Their distinction is based mainly on the topography of their internal scour surfaces and bedding planes as well as their stratigraphic position with respect to channel facies.

2.3.1.1. Inner-bank levee subfacies : description

The inner-bank deposits overlie point-bar sandstones and are composed of up to 3 metres of thinly-bedded sandstone/siltstone couplets with characteristic undulating or "swaley" bedding planes and, in places, prominent internal erosion surfaces with a stepped or "terraced" topography.

Figure 19 is a detailed panel section from the Leeu River transect shown in Appendix Figure 6 that illustrates the nature of the transition from upper point-bar facies into the overlying inner-bank levee deposits. The boundary between the two facies is sharp on top of the protruding accretion ridges but becomes diffuse or gradational in the mudrock filled swales. Because these two facies are so closely inter-related, it is difficult to define a lithological boundary between them. In this sequence the boundary is drawn by interpolating an undulating contact between the convex upper surfaces of point-bar ridges and the flat-to-concave top of mudrock-filled swales thus excluding the sandier swale-fill from the inner-bank subfacies.

The characteristic undulating bedding planes of the inner bank levee deposits are a direct reflection of the underlying point-bar topography. The sandstone/siltstone couplets drape the accretion ridges and swales with only a slight increase in bed thickness in the depressions. Thus it appears that the inner bank levee deposits maintained a corrugated surface topography long after the original point-bar ridges had been buried.

Figure 19 illustrates another diagnostic feature of inner bank levee deposits, namely high angle internal erosion surfaces. This particular style of discordant bedding is manifest in erosively-based +/- 30 cm thick lenses of fine-grained, ripple cross-laminated silty-sandstone bedded at angles up to 35 degrees from horizontal (see Fig. 23). Successive sandstone/siltstone couplets lie conformably on the sloping upper surface of the sandstone. Although these sandstone lenses

FIG. 23 Inner-bank levee deposits showing a sandstone lens bedded at a high angle discordantly cutting the horizontally bedded mudrocks beneath with successive sandstone/siltstone couplets lying conformably on its sloping upper surface. Person for scale.

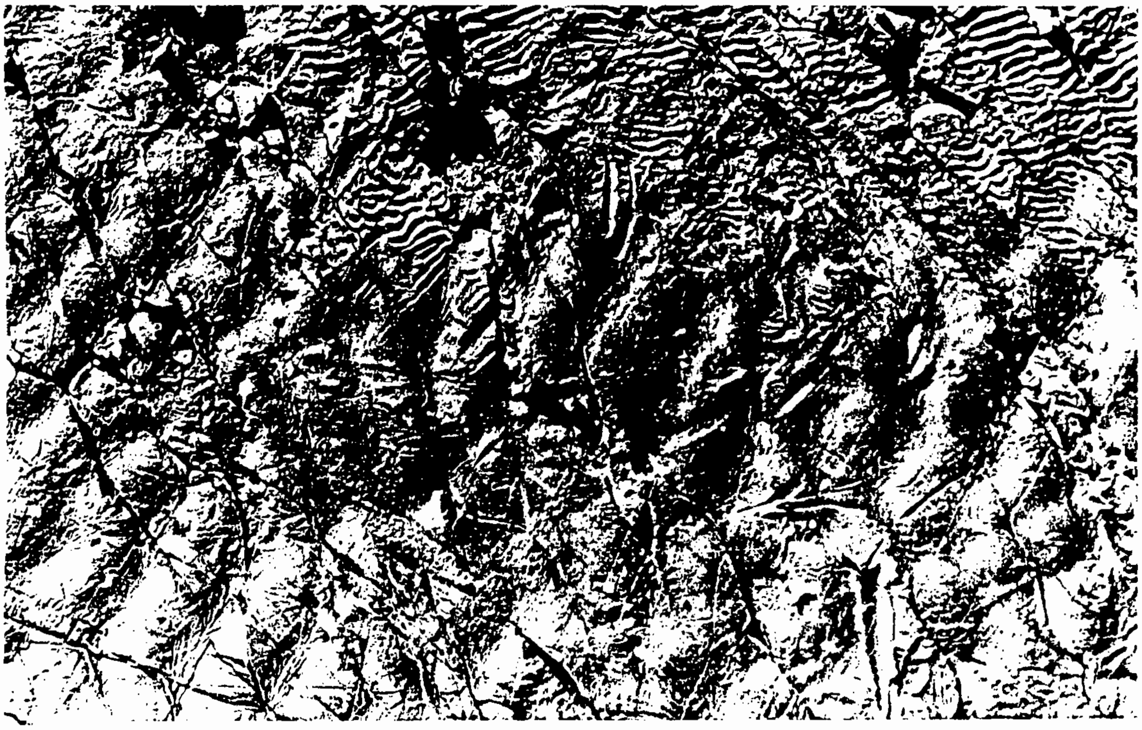


FIG. 25 An exhumed inner bank levee sandstone surface on the farm Vaalkoppies on the Beaufort West commonage. A detailed plan of this surface is included in Appendix Fig. 10. Note the oscillation ripples and tool marks superimposed on the primary ripples that were formed under a unidirectional flow from right to left. The shape and orientation of the tool marks suggests that they were made by floating vegetation. Field of view is approximately 2 m x 1.5 m.

FIG. 24 Striated groove cast on the underside of an inner bank sandstone lens. Matchbox 5 cm long.

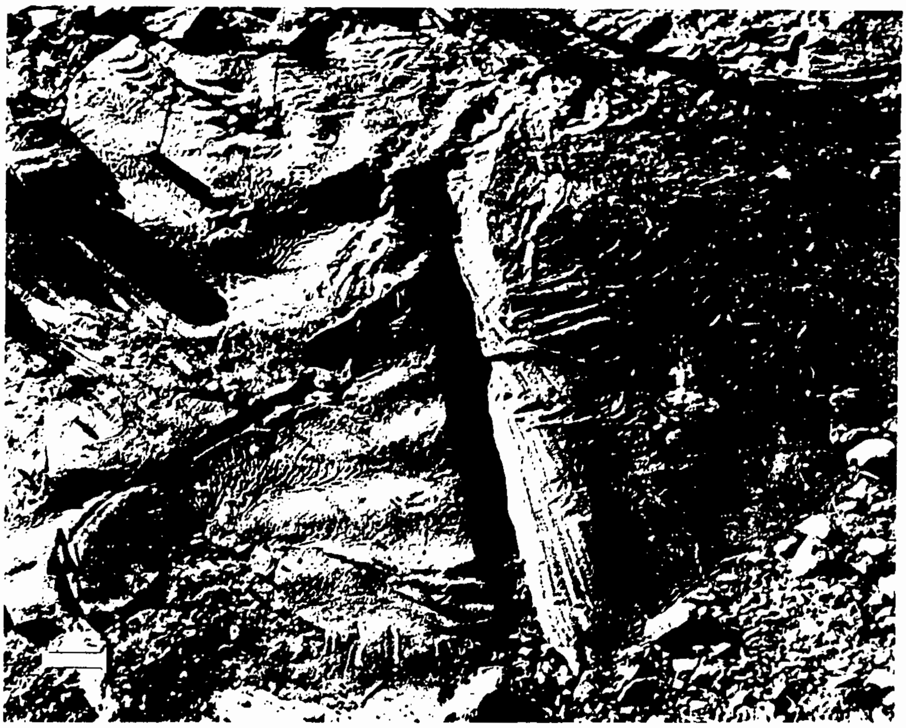


FIG. 26 Close-up of a tool mark on the Vaalkoppies levee surface. Note the striations on the cut edge of the notch. The rill marks indicate that the palaeoslope was down to the left. Scale bar 2 cm.

overlie a concave erosion surface, they do not have channel-shaped profiles. The erosion surface continues beyond the sandstone lens as a inconspicuous low-profile disconformity in the swaley bedding before it again steps-up and is again overlain by a sandstone lens bedded at a high angle. Thus the internal erosion surfaces within the inner bank levee deposits appear to have a characteristic stepped or "terraced" topography on which coarser material is deposited or preferentially preserved only on the steeper slopes.

Striated groove-casts and load-casts are commonly preserved as sole structures on the sand lenses (Fig. 24) and are generally aligned parallel to dip suggesting that there has been some post-depositional downslope slipping and slumping.

The upper surface of the high angle bedded sand lenses in the study areas display a variety of structures such as current ripples, prod, skip and brush marks, rill marks, falling water-level marks and invertebrate tracks and trails.

Markings on the surface of an inner-bank levee sandstone exposed in the Beaufort West Commonage (see Fig. 25) were mapped in detail on a 50 cm grid. A compilation of this is included in Appendix Figure 10. The cross-cutting relationships of various sedimentary, erosive and biogenic structures on this surface record a sequence of events that probably took place during a single overbank flood, resulting in deposition, sculpturing and eventual burial of the levee sand lens. The 15 cm thick sandstone is bedded at approximately 20 degrees from horizontal and occurs within a sequence of alternating lenticular sandstones and siltstones approximately 0.7 m above the undulating top of a 2 m thick channel sandstone. Appendix figure 10 shows the obliquity of straight-crested ripples on this surface formed in a unidirectional current that was possibly also responsible for eroding the linear "notch" into the existing levee deposits along which the sand body was deposited.

The sandstone lens has a concavo-convex cross-sectional profile and is elongate along the primary palaeoflow direction. In several places, the ripple crests have been scoured, brushed and prodded by floating debris to form a series of lipped

FIG. 27 One of the mysterious bilobed meniscoid trails on the Vaalkoppies sandstone that appear to have been made by the crawling or furrowing behaviour of a bilaterally symmetrical animal moving from the lower submerged to upper exposed part of the levee surface. These trails may have been made by lungfish. Scale bar 10 cm.

FIG. 28 Pairs of sinusoidal grooves on the Vaalkoppies surface are attributed to scour by the caudal and pectoral fins of fish. Dendritic run-off rills are developed in most of the primary ripple troughs. As flow coalesced, the resultant scour built small sand bars that encouraged the flow to overtop the crests into the downslope ripple troughs. Scale bar 2 cm.

prod-marks and linear grooves, most of which are parallel to the direction of primary flow (see Appendix Fig. 10 and Fig. 26). As flow waned, the water-level dropped slowly at first allowing a series of oscillation ripples, with crests parallel to the strike of the sand body, to be formed at the waters edge (Fig. 25). By this time, vermiform invertebrates burrowed through the sand layer from beneath and emerged onto the thin mud veneer that had begun to settle onto the surface. Three mysterious meniscoid traces are displayed on this surface that appear to have been made by crawling or furrowing behaviour of a bilaterally symmetrical animal, possibly a lungfish (Fig. 27). Pairs of sinusoidal grooves on the surface (*Undichnus*) are attributed to scour by the ventral and caudal fins of fish swimming in shallow water (Fig. 28). The final scupturing event took place during emergence of the surface after the water level dropped more rapidly. Expelled interstitial water ran downslope, following the primary ripple troughs, forming dendritic rills. At several points along each of the more obliquely-oriented ripple troughs, the run-off flow became strong enough to overtop the retaining ripple crest and continue down the adjacent trough (Fig. 28).

The lack of desiccation cracks on this surface indicates that its emergence was short-lived, possibly only a matter of hours before another flood surge raised the water-level again and deposited the overlying layer of silt.

2.3.1.2. Outer bank levee subfacies : description

Sedimentological logs of the interchannel strata show that levee-type sequences with similar sandstone/siltstone couplets, of comparable thickness may be encountered two or three times in a single interchannel section (eg. Appendix Fig. 11). These sequences are interpreted as outer-bank levee deposits laid down on the concave banks of large meandering rivers. The main sedimentological differences between the outer bank levee deposits and the previously described inner bank facies are that they are not associated with upper point-bar deposits, they do not display wavy or "swaley" bedding and their internal scour surfaces are much smoother and non-terraced. They do, however, contain isolated channel-shaped scours up to 10 m wide and 2 m deep, conformably filled with sandstone/siltstone couplets and interpreted as crevasse channel-fills (Appendix Fig. 11).

Outer bank levee deposits in the Leeukloof panel section (sections b and c of Appendix Fig. 8) contain two low-profile scoured surfaces, each overlain by a thin layer or several lenses of fine-grained sandstone containing invertebrate burrows and possible root moulds. These sandstones commonly grade upwards into flat-bedded massive green siltstone. This is followed by a series of 20 - 30 cm thick greenish sandstone/siltstone alternations before passing into more thinly-bedded fissile dark reddish-brown silty mudstone.

Therapsid fossils are locally common in these deposits and are invariably peri-mineralized with smooth-surfaced calcareous nodular material. In the Leeukloof section there is a concentration of fossils in association with the basal scour surfaces of the outer-bank levee deposits (Appendix Fig. 8). These fossils and their modes of occurrence are described more fully later in this report.

The outer-bank levee sequences are commonly terminated by the base of laterally continuous, tabular, thin (0.4 m) fine-grained sheet sandstone bodies that are interpreted as crevasse-splay deposits. Sandstone-filled mudcracks are often preserved as sole structures on the sharp, but mostly non-erosive basal surfaces of these sandstones. The upper contacts are usually sharp and commonly rippled or covered with polygonal desiccation cracks. Rarely, the upper boundaries are gradational with overlying mudrocks. A more detailed description of the crevasse-splay sandstones follows in the next section where they are included as a subfacies of the proximal floodplain facies.

Crevasse channel-fills contain more siltstone and mudstone than sandstone and are recognizable in cliff sections by their 'U'-shaped conformable or parallel bedding overlying an irregular erosion surface (see Appendix Fig. 11). The lower part of the channel-fill contains fine-grained burrowed sandstone lenses, the upper parts consist of thinner sandstone/siltstone alternations which are almost horizontally bedded and identical to the overlying strata. Large irregularly-shaped calcareous nodules containing root moulds and worm burrow casts are developed in the upper portion of the crevasse channel-fill.

The exhumed crevasse-splay sandstone that appears to have emanated from the apex of point-bar 2 of the Reiersvlei sandstone (see Fig. 8) is no longer in lithological continuity with the nearby channel-fill deposits. The outer-bank levee deposits that contained the crevasse channel-fill have been completely removed. This suggests that the crevasse channel-fill lithology was either predominantly mudrock or at least not arenaceous enough to resist erosion. The conformably-bedded sandstone lenses would have collapsed and disintegrated as the supporting mudrocks were denuded. Thus the lithology and bedding characteristics of crevasse channel-fills may actually promote more rapid weathering once they are exposed.

2.3.2. Hydrodynamic Interpretation of Channel Bank Deposits

The sediments, sequences and structures of the channel bank facies are similar to those described from the levees of modern floodplains. (eg. Fisk, 1944; Allen, 1965; McKee et. al, 1967; Coleman, 1969; Singh, 1972; Ray, 1976; Nanson, 1980; Farrell, 1987). The basic increment of sedimentation on both concave and convex banks of the ancient meanders consisted of a fining-upward sand to silt flood couplet that ranged in thickness, after compaction, from 2 - 30 cm. It was deposited on a surface that had previously been scoured and, in places, eroded. The couplets were capped with a veneer of clay-rich mud which is now only patchily preserved, having survived the extended periods of sub-aerial desiccation, bioturbation, plant colonization and pedogenesis that followed each flood episode.

The basic sandstone/siltstone couplets or bedsets (Bridge, 1984) are interpreted as having been rapidly deposited during a single, short-lived flood event mainly by vertical accretion from unconfined sheet flow spilling over the channel banks.

The textural fining reflects a relatively rapid change in flow regime as the flood subsided. Decelerating flow velocities, decreasing water depths and a rapid fall-off in the amount of bedload supplied to the levees from the main channel, all contribute to the sudden switch from traction load dominated (sand) to suspension load dominated (silt) sedimentation on the channel banks (Pizzuto, 1987).

Another basic sedimentary feature of levee deposits, apart from the fluctuating hydrodynamic conditions during deposition, is the steadily decreasing rate of sedimentation with increasing distance from the main channel. This is due to the fact that the principal channels are the main suppliers of sediment and that the capacity for overbank flow to transport this sediment is first exceeded in the channel bank areas at the point where flow becomes unconfined. As a result, accumulations of sediment are thicker on the banks than further into the floodbasin and natural levees are formed.

Pulsatory waning of floodwaters is evidenced by the intermittant emergence of sand bars deposited during rising flood stages along notches eroded into the inner-bank levee surface. The preservation of ripple and ripple-drift cross-lamination in the thicker silty-sand lenses suggests that the coarser levee materials were rapdily deposited under upper lower-flow regime conditions (McKee, 1966; Ray, 1976). The greenish siltstones and reddish-brown mudstones of the levee deposits have no discernable sedimentary structures. This possibly resulted from the rapid "dumping" of suspended sediment when formerly channelized floodwaters lost competence as they spilled over the levee surface (Ray, 1976). In addition, the passage of the muddier, more organic-rich strata through the gut of sediment ingesting worms, and their physical disruption by invertebrate burrowers and plant roots may have completely obliterated primary structures in levee deposits. Farrell (1987) noted that primary stratification in the upper parts of sand/mud flood rhythmites that make up the Mississippi River levees, is invariably obliterated by biogenic and pedogenic overprinting.

The "swaley" bedding that characterizes the inner bank levee deposits of the Teekloof Formation is well documented from modern high sinuosity rivers such as the Mississippi (Fisk, 1944), the Ore (Nilsson and Martvall, 1972) and the Beatton (Nanson, 1980). Nanson (1980) noted that the point-bar accretion ridge topography was perpetuated through an overlying succession of over 2 m of essentially vertically accreted overbank deposits in the Beatton River of British Colombia. He concluded that ridge and swale topography was probably maintained by secondary currents generated on either side of the scroll bar during floods. These currents tend to converge downstream and towards the crest and, in doing so, they redistribute some of the swale sediments towards the ridge, thus maintaining its relief.

Because the vertically accreted bar-top levee deposits are so closely associated with the laterally accreted point-bars several studies of contemporary river deposits have included them within the channel facies as "a vertical component of lateral accretion" (Nanson, 1980; Jackson, 1981; Ray, 1976; Singh, 1972). Facies analysts of ancient fluvial deposits, however, have tended to group these strata with the overbank or floodplain deposits not only on lithological grounds, but also on recognition of their vertical accretion characteristics (eg. Moody-Stuart, 1966; Leeder, 1973; Graham, 1975; Fielding, 1986).

The present facies study recognizes that the inner bank levee deposits are a sedimentologically defined unit but accepts that they are transitional both spatially and hydraulically between channel and overbank depositories. For ease of description, a lower boundary has been defined between the ridge and swale corrugated surface of the upper point-bar and the overlying inner bank levee subfacies. The former is allocated to the channel facies association and the latter to the interchannel facies association.

Apart from "swaley" bedding, the inner bank levee deposits are also characterized by stepped or "terraced" internal erosion surfaces overlain, in places, by discrete lenticular sandstones. Similar discrete local lenticular masses of channel-type pervious sands occur in the topstratum deposits of the Mississippi floodplain (Fisk, 1944). They are especially prevalent in the downstream portion of a bend where they merge with upper point-bar deposits.

Palaeosurfaces preserved on top of the levee sandstone lenses confirm that sudden changes in hydraulic regime took place during their formation and that they were temporarily exposed during waning flood stage. They also bear evidence of tool marks that could only have been made by floating vegetation. Modern levees are usually well vegetated and following a flood event they are often littered with driftwood and leaves, especially in the swales (Fisk, 1944). It is likely that floating vegetation was stranded high up on the point-bars and levees of the Teekloof rivers too, but extended periods of sub-aerial exposure prevented its preservation.

The "stepped" erosion surface and high angle sandstone lenses of the inner-bank levee deposits probably resulted from a flash-flood event whereby discharge in the main channels increased very rapidly with a simultaneous increase in flow depth and velocity possibly in the form of a "standing wave" (Stear, 1985). Scour and erosion of levee deposits during rising flood is a common phenomenon especially on the upstream edge of inner bank levees (Nanson, 1980) and in open-ended swales (Scmudde, 1963). The eroded "notches" in the Teekloof inner bank levees are interpreted as having been cut by exceptionally large flood surges during rising flood. As flow depths increased to overtop the levees, the thalweg migrated towards the inner bank (Jackson, 1976) initiating sand bed movement on the lower and middle point-bar surface and into the eroded levee notch.

The outer bank levee deposits contain low profile scoured surfaces without erosion notches. Their absence may simply be a consequence of lack of preservation in that levee deposits immediately overlying the cut-bank are constantly being eroded as the meander expands. Thus the near-channel portions of these outer bank deposits in which the erosion notches are formed are not accumulating in the preserved sedimentary pile to the same degree as those of the inner bank levees.

Conformable channel-fill bedding is recognized as a characteristic feature of levee deposits of the Gomti River, India (Singh, 1972) and is attributed to the development of, and deposition in, crevasse channels. Such channels are cut by overbank flow as it streams through low points in the natural levees. In a high sinuosity system, crevassing is most likely to occur on the outer side of tight meanders where the thalweg impinges on the channel bank. This commonly occurs just downstream of the meander apex (eg. Fisk *et al.*, 1954; Arndorfer, 1973; Farrell, 1985) and it is, therefore, predictable that fully-developed crevasse channels would be most frequently encountered in outer bank levee deposits, as is the case in the Teekloof Formation.

The repeated occurrence of outer bank levee deposits in a single interchannel section is an indirect record of the migration behaviour of the contributing channel or channels. The sudden appearance of outer bank levee deposits above an extensive erosion surface cut into previously deposited floodbasin sediments (as in the Leeukloof panel section) is interpreted as the floodplain record of a major channel avulsion into this part of the floodbasin (Bridge, 1984; Farrell, 1986). The gradual upward transition from outer bank levee to more distal floodplain deposits in the Wilgebosskloof panel section is interpreted as recording the migration of the channel-belt away from this part of the floodbasin (Bridge, 1984). Repeated occurrences, in the interchannel sections, of outer bank levee deposits that overlie locally developed erosion surfaces are possibly the result of levee progradation from nearby distributary channels (Fisk, 1944). The preserved coarse member of these non-migratory, low-sinuosity floodplain channels is described in the following section under "shoestring" sandstones.

2.3.3. Proximal Floodplain Facies

Proximal floodplain deposits make up the bulk of the interchannel facies association. They consist of 2 - 8 m sequences of 0.3 - 0.75 m thick siltstone beds each capped with minor (<0.05 m) silty mudstone layers (see Appendix Figs 8, 9, 11 to 18). Rarely coarsening-upward sequences are manifest in fresh outcrops as +/- 1 m thick sharply-based siltstone beds that gradationally pass into faintly ripple cross-laminated very fine-grained sandstone. The mudrock colours range from green to grey to maroon and do not always conform to lithological boundaries. Colour mottling is common, usually involving mixtures of maroon and green hues. Some fresh outcrops reveal a repeated sequence of colours. Within an approximately 1 metre sequence from a sharply-based green siltstone the mudrocks gradually become dotted with maroon mottles before passing up into a thin bed of fissile-weathering dark reddish-brown silty mudstone.

This colour sequence is interpreted as the result of sub-aerial exposure and desiccation of the surficial alluvium and pedogenic modification of the subsurface. Abundant palaeopedogenic calcrete nodules of various shapes and textures occur in the proximal floodplain mudrocks. These are described more fully in the following chapter dealing with palaeosols.

Therapsid fossils are scattered throughout these deposits becoming more common in association with extensive internal scour surfaces and well-developed pedogenic horizons (see Appendix Figs 8 and 9). Fossils are invariably peri-mineralized with micritic nodular material. Their taphonomy and modes of preservation are discussed later.

Proximal floodplain sequences are commonly interrupted by 0.3 - 2 m thick tabular sandstone sheets with flat non-erosive bases and either sharp or transitional upper contacts. These are interpreted as crevasse-splay sand sheets deposited mainly during major floods by floodwaters emerging from gorge-like crevasses cut into the natural levees. They are regarded as a discrete subfacies of the proximal floodplain.

A less common, more restricted subfacies of the proximal floodplain deposits are narrow, slightly sinuous, "shoestring"-shaped sandstones interpreted as the preserved channel deposits of distributaries that drained the ancient floodplains and probably issued into distal floodbasin lakes.

2.3.3.1. Crevasse-splay subfacies

Crevasse-splay sandstones that are interbedded in the proximal floodplain facies are commonly bounded by sharp contacts. They have flat, smooth bases and slightly undulating tops with a tabular cross-sectional profile, quite distinct from the lenticular sandstones of the channel-bank facies. The Reiersvlei sandstone exposure (Fig. 8) shows that in plan they have a fan or lobe shape spreading in a basinward direction. On the ground this feature is a 0.5 m thick tabular sheet of fine-grained, horizontally-laminated sandstone with minor ripple cross-stratification and rare trough cross-bedding. Palaeocurrent readings on this surface confirm that it was deposited by flow emanating from the associated meander (Fig. 11).

Inter-channel sequences may contain up to 6 crevasse-splay sandstones (see Appendix Figs. 7, 8, 9, 11 and 15) some of which persist laterally for up to 1.5 km before gradually wedging out or splitting into 3 or 4 thin sandstone stringers each terminating in a series of slump balls. Sole structures on the basal surface include mudcracks and, rarely, vertebrate burrow casts (Figs. 29 and 30). Because this contact is non-erosive, in cliff sections they provide an easily observed topographic profile of the ancient floodplain surface. These sandstones terminate both sedimentary and pedogenic sequences and are, therefore, potentially an important sub-environment of the floodplain.

Two cliff section exposures of crevasse-splay sandstones were extensively logged to investigate their depositional history; one forms the basal unit of the Waterval multi-storied channel sandstone (Appendix Fig 5), the other is exposed in the banks of the Leeu River on Amandelboom (Appendix Fig. 22). The Amandelboom crevasse-splay sandstone comprises three vertically superimposed sedimentation units, a lower planar cross-bedded sandstone, a middle mudrock unit and an upper parallel-bedded sandstone unit with slump and dewatering structures.

FIG. 29 Lateral view of an in-situ sand-filled helical burrow beneath a crevasse-splay sandstone of identical lithology. The flat non-erosive base of the crevasse-splay sandstone defines the original surface onto which the burrow opened. Scale in cm.

FIG. 30 Close-up of the terminal chamber of a sand-filled decline burrow in continuity with the base of a crevasse-splay sandstone (at hammer head). A *Diictodon* skull lies ventral-up at the base of the terminal chamber, just above the lens cap (arrowed).

The lower unit rests on a flat pitted and matted surface and consists of a series of compound meso-scale bars. Horizontally-laminated sand with low angle intersections was deposited between large broad-based planar cross-bedded convex sand bars some 20 m wide by 1.5 - 2 m high. Shallow trough cross-bedding is developed within some of the bars but they appear to have been mainly formed by the superimposition of several straight-crested sandwaves.

Complete meso-scale bar-forms, with both lee and stoss side laminations, are preserved on the non-eroded upper surface of the sand bar complex (see Appendix Fig. 22). The steeply dipping foreset laminae (up to 34 degrees) with scattered mudstone chips, the convex-up internal discontinuity planes and the cross-sectional shape of these meso-scale bars are similar to those of dome-shaped aeolian dunes (McKee, 1966). At one point the toe of one of the dunes is interbedded with the overlying conformably bedded mudrocks that fill the inter-bar concavity (Fig. 31). Conformably bedded siltstone/sandstone couplets overlying the lower unit extend up the flanks of the sand bars and, in places, onto the top.

The upper sandstone unit, unlike the lower, is erosively based and appears to have removed much of the mudrock interval. It is made up of horizontally and parallel-bedded fine-grained sandstone with abundant soft-sediment deformation structures (Fig. 32). The upper unit channels appear to have preferentially followed linear depressions between the bars of the lower sand unit. Flame-shaped convolutions (Fig. 33) are common in the mid-channel portions of the upper sandstone whereas pillow-shaped slumps are common in the basal sands of the descending channel walls (Appendix Fig. 22). Towards the top of the upper unit, thin veneers of mudcracked maroon-coloured siltstone form continuous partings that preserve sandstone surfaces covered in straight - or slightly sinuous - crested small current-ripple forms (Fig. 34).

The Amandelboom crevasse-splay sandstone is overlain by massive siltstones of the proximal floodplain facies and underlain by thinly bedded sandstone/siltstone couplets of channel bank facies, illustrating the fact that crevasse-splay sands commonly represent an abrupt change in floodplain sedimentation.

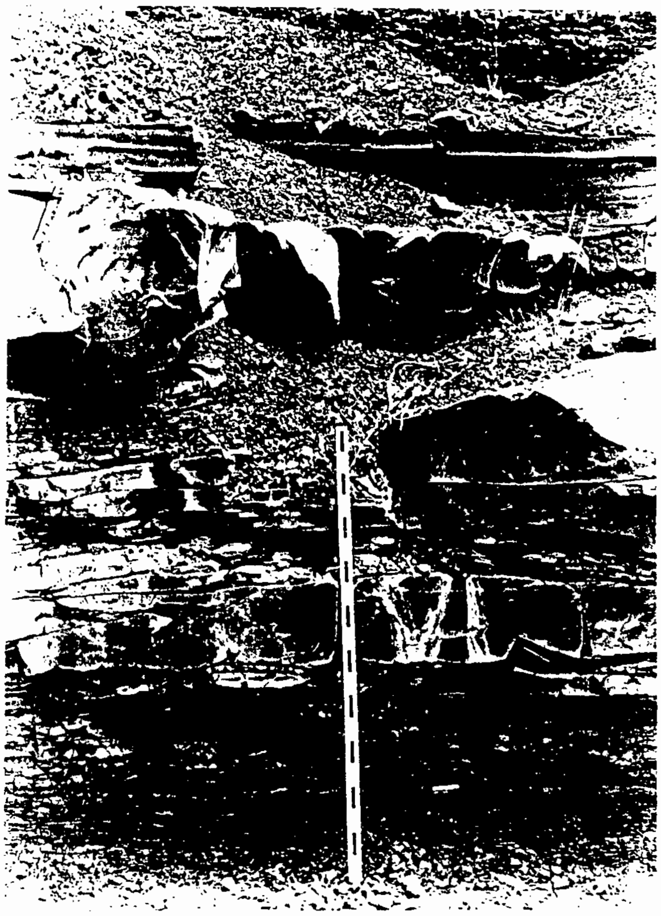


FIG. 31 View of metre 94 of the Amandelboom crevasse-splay (see Appendix Fig. 22) showing some of the characteristics of the three superimposed depositional units that make up the entire crevasse-splay lobe. Note the flat base and smooth-topped convex upper surface of the lower sandstone unit as it toes into the thinly-bedded siltstone/mudstone couplets of the middle unit. Note also the erosively-based and slumped upper sandstone unit with its flat, ripple-sculptured upper contact. Staff is 1 m long.

FIG. 32 Soft-sediment deformation in the upper sandstone of the Amandelboom crevasse-splay at metre 61 of Appendix Fig. 22. Scale in cm.

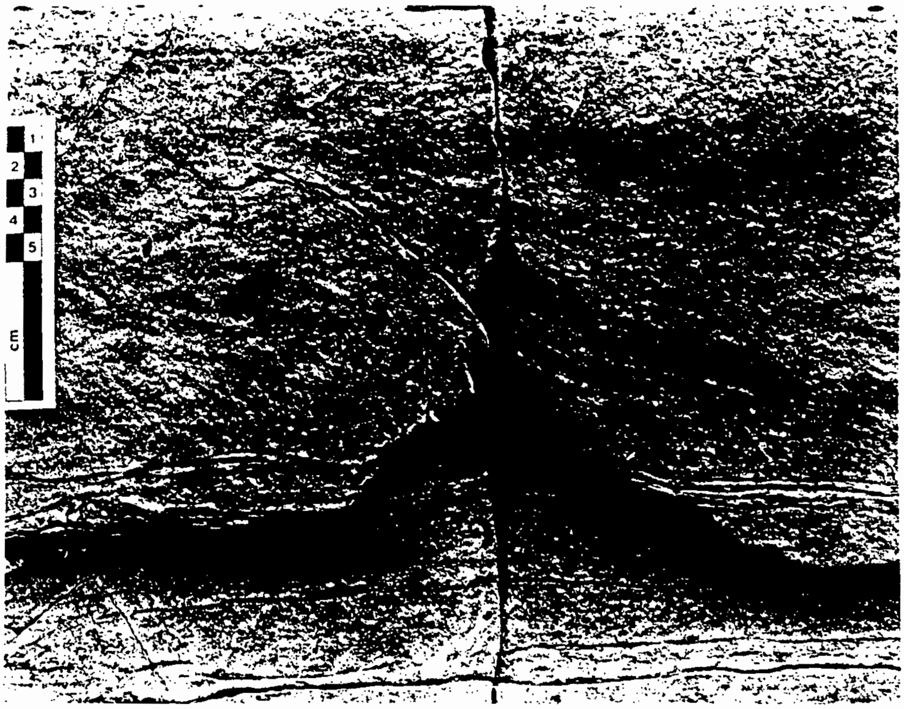


FIG. 33 Dewatering flame structure in upper unit of the Amandelboom crevasse-splay sandstone at metre 90 of Appendix Fig. 22.

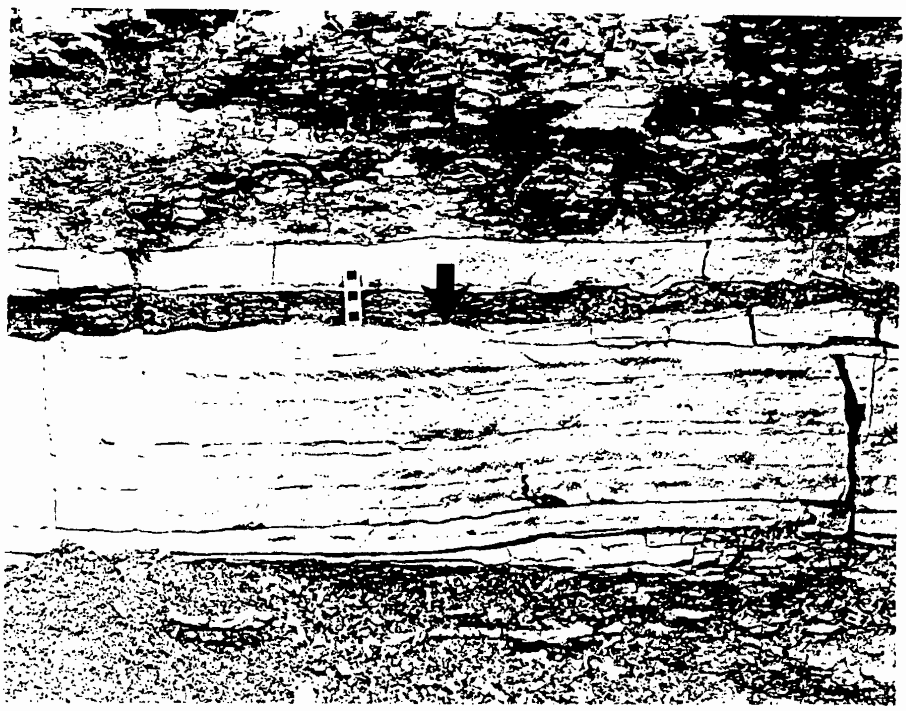


FIG. 34 View of rippled surfaces preserved on top of the upper sandstone unit of the Amandelboom crevasse-splay at metre 134 (see Appendix Fig. 22). Scale in cm.

At metre 24 of Appendix Figure 22 there is a set of three vertically stacked mudrock-filled cavities in the sandstone cliff. These unusual structures may have originally been tree roots although a similar feature in a crevasse-splay sandstone nearby contains an articulated *Diictodon* skeleton (Fig. 35) indicating that they are most probably of vertebrate origin.

The Waterval crevasse lobe (Appendix Fig. 5), in contrast to the multistoried Amandelboom crevasse-splay sandstone, is a homogeneous, sharply-contacted single storied sandstone body that outcrops for 1.5 km without becoming thicker than 2 m. The sandstone is fine-grained and predominantly horizontally laminated in places grading into climbing ripple cross-lamination (Fig. 36). Isolated conformably-filled channels occur beneath the upper contact. The latter is smooth-surfaced and undulatory and displays large-scale desication cracks although much of this surface has been eroded by the succeeding channel. Palaeocurrent measurements show that the crevasse-splay had a north-easterly flow as opposed to the north-westerly flows of the two overlying channel units.

2.3.3.2. Distributary channel subfacies

Narrow, slightly sinuous, "shoestring" sandstone bodies within the interchannel deposits are interpreted as the coarse member of distributary channels that drained the floodplains. Three-dimensional exposures on Reiersvlei and Leeukloof (Figs. 8 and 9) show these sandstone bodies to be up to 4 km long, 50 - 100 m wide and 5 - 7 m thick in the centre, thinning laterally.

In places these sandstones have erosive contacts with the Reiersvlei sandstone indicating that they are a resistant component of the interchannel sediments that buried the abandoned meanderbelt. Other outcrops appear to be made up of two superimposed shoestring sandstones presenting a "plaited" planimetric pattern.

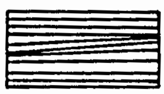
The basal surface is undoubtedly erosional although it is rarely overlain by intraformational mud-pebble conglomerate, and more often it is covered with

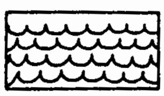
FIG. 35 Sandstone-filled helical burrow in crevasse splay deposits. Arrow indicates skull of articulated *Diictodon* skeleton.

FIG. 36 Close-up of unit 1 of the multistoried Waverval sandstone at metre 175 of Appendix Fig. 5.1 showing a preserved hydraulic "jump" from plane-bed to ripple-drift sedimentation that migrated upstream through time. Flow was from left to right.

LEGEND TO LEEUKLOOF CLIFF SECTIONS

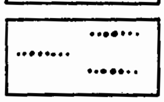

TROUGH CROSS-BEDDING

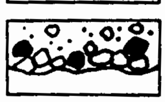

HORIZONTAL LAMINATION WITH SOME LOW ANGLE INTERSECTIONS

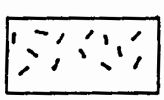

SMALL CURRENT RIPPLE CROSS-STRATIFICATION


IN-DRIFT RIPPLE CROSS-STRATIFICATION


IN-PHASE RIPPLE CROSS-STRATIFICATION


STRUCTURELESS SANDSTONE


CLAST-AND MATRIX-SUPPORTED MUDROCK PEBBLE CONGLOMERATE. SHADED CLASTS ARE PEDOGENIC NODULES


ISOLATED MUDROCK CLASTS


HORIZONTALLY-BEDDED SANDSTONE WITH NUMEROUS SILTY PARTINGS AND BURROWS

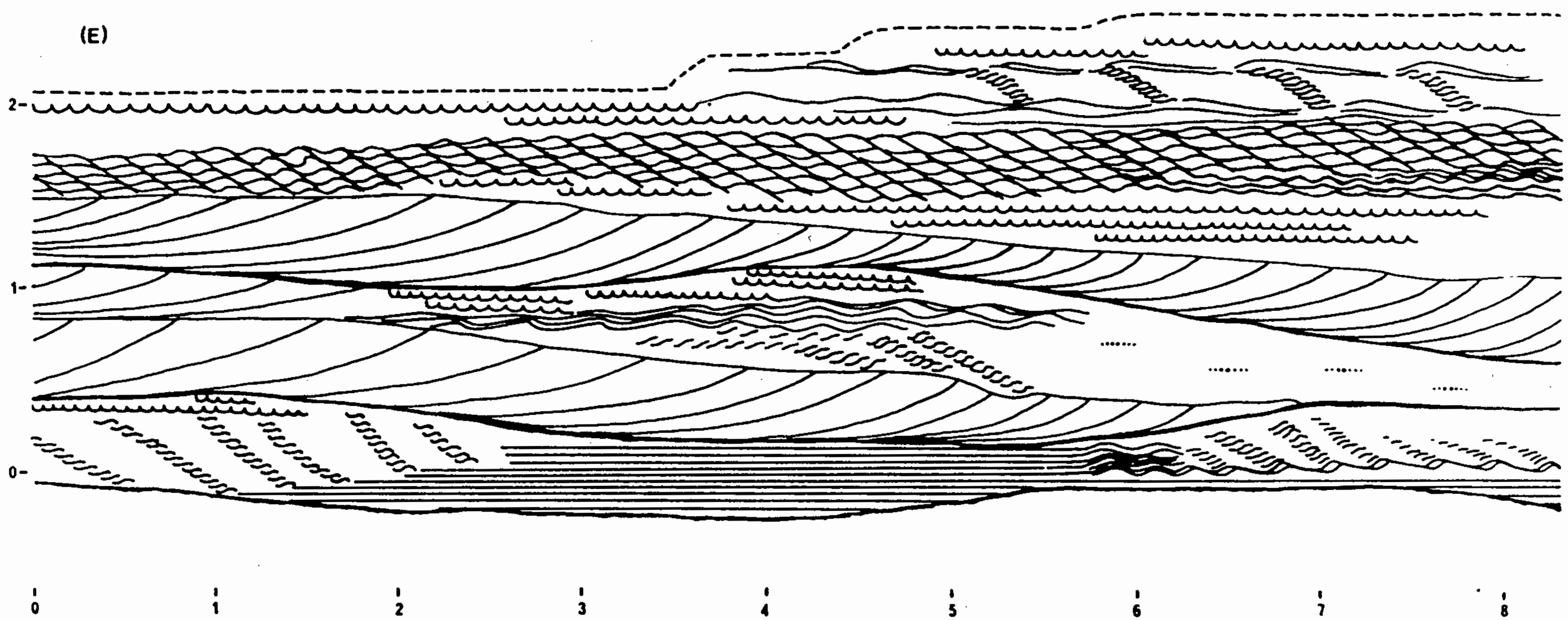


FIG. 37 Panel section of a cliff exposure of a "shoestring" sandstone on Leeukloof (locality E of Fig. 12) showing major bounding surfaces and sedimentary structures. Note the long continuous successions of trough foresets that characterise these outcrops and the steep angle of climb of the ripple-drift cross lamination. Scale in metres.

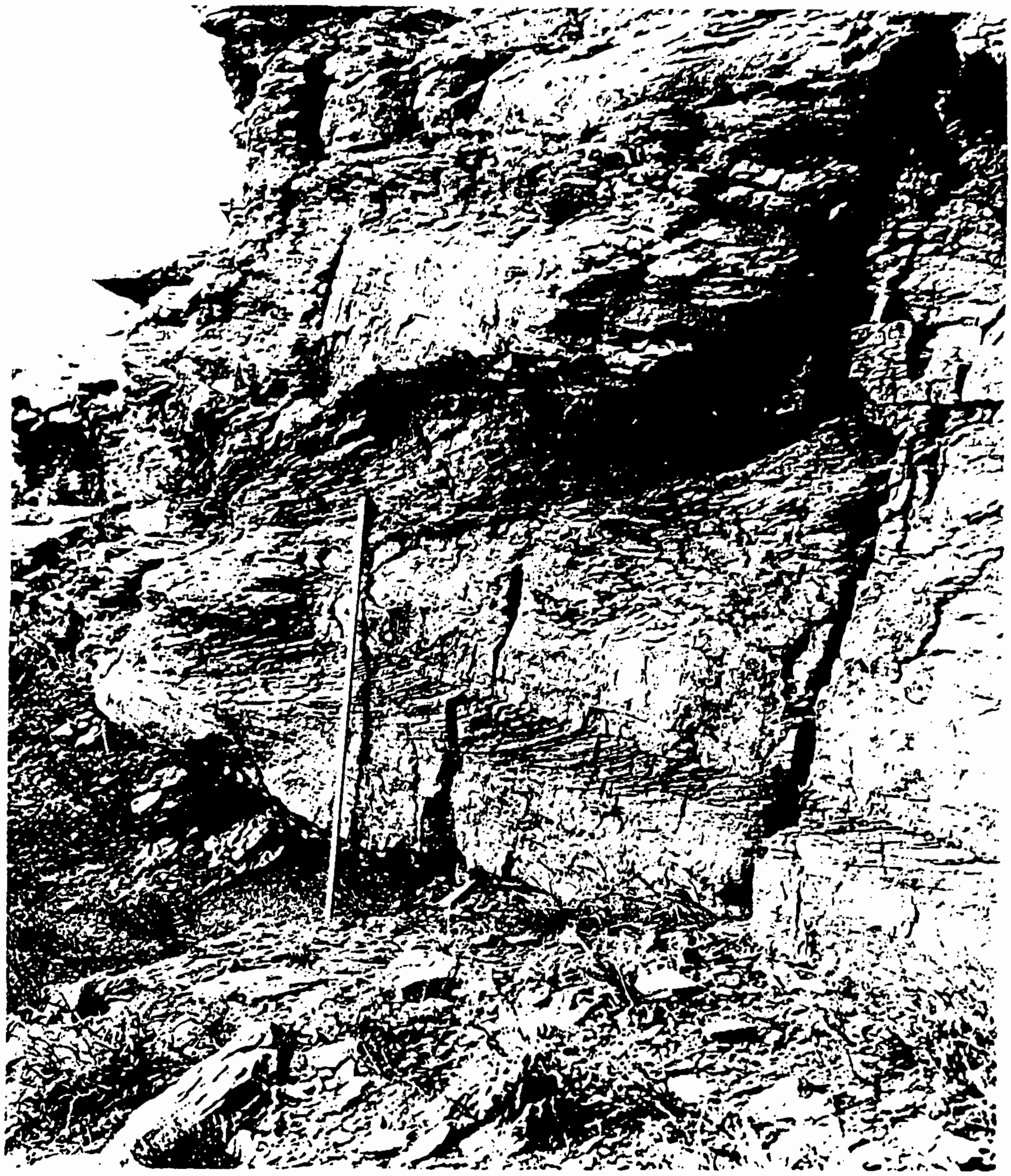


FIG. 38 Looking "downstream" along a "shoestring" sandstone exposure on Leeukloof (Locality E of Fig. 12). Staff is 1 metre.

horizontally laminated fine-grained sandstone which passes laterally and vertically into in-phase and in-drift ripple cross-laminated sandstone (see Fig. 37). These beds are succeeded by two or three single sets of erosively-based trough cross-bedding that fills long shallow troughs in the bed (Fig. 38). Each set is succeeded by ripple cross-laminated and massive sandstone. The topmost strata consist almost entirely of climbing-ripple cross-laminated fine-grained sandstone.

Palaeocurrent trends conform closely with the orientation of the sandstone body as a whole and parallel the outcrop in most cases (Fig. 12). Most of the "shoestring" sandstones exhumed with the Reiersvlei sandstone show a broad north-easterly palaeoflow direction although some segments of these channels may follow an apparently erratic course with sharp 90 degree turns.

2.3.4. Hydrodynamic Interpretation of the Proximal Floodplain Facies

Sedimentation on the proximal or near-channel floodplains of the Teekloof Formation was by vertical accretion from episodic sediment-laden overbank sheet floods that flowed over the main channel banks and, to a lesser extent, from distributary and crevasse channels. The gentler gradients of the proximal floodplain caused floodwaters to lose competence to transport their suspended load resulting in the rapid "dumping" of thick layers of suspended silts and very fine sands (Pizzuto, 1987; Ried and Frostick, 1987).

Narrow, slightly sinuous distributary channels and crevasse-splay fans provided the only relief on an otherwise featureless floodplain. Slightly higher-energy overbank flows from these channels probably resulted in the more localized scour surfaces and the accumulation of patches of bedload-transported sand and disarticulated therapsid bones. The lack of sedimentary structures in the siltstones is possibly a reflection of rapid "dumping" of fines from turbulent suspension (Pizzuto, 1987) where churning of the newly-deposited thixotropic sediment by current shear caused the destruction of primary stratification. Thin silty-mudstone layers and veneers that terminate the fining-upward flood cycles indicate that, for a period at least, much of the floodplain remained covered with standing or very slowly moving water allowing the settling of fine silt and clay particles.

Between flood events, there is evidence for extended sub-aerial exposure leading to drying-out of the surficial alluvium followed by plant colonization and pedogenic modification. The degree of maturity of the floodplain soils and stage of sub-aerial weathering of mammal-like reptile bones are indirect measures of the frequency of floodplain inundation. These parameters are discussed in more detail later in the thesis but it is clear that crevasse-splay developments had a major influence on the local rates of sedimentation on the proximal floodplain.

The crevasse-splay sandstones all have an overall sheet-like geometry, as if deposited from non-channelized flow. However, some have complex internal sedimentary discontinuities indicating that on parts of the splay, for at least some of the time, flow was channelized. The Waterval and Amandelboom crevasse-splay sandstones differ in their internal structure in that the former is a single, homogeneous unit and the latter is made up of three heterogeneous sedimentary units. The Waterval splay is interpreted as having been deposited and abandoned in a single sheet-flood event. The Amandelboom splay has the geometry and composition of a more fully-developed crevasse-splay with an anastomosing channel network that contained continuous flow for much longer periods.

The horizontally-laminated fine-grained sand of the Waterval splay lobe was deposited under upper-flow regime conditions with fluctuating velocities (Pettijohn, 1957). The lateral and vertical transition to climbing-ripple cross-lamination is indicative of the initiation of deposition of suspended sediment from a decelerating flow on a flat bed and the transition from laminar to turbulent boundary conditions (Jopling and Walker, 1968).

Under arid zone, flash-flood-type hydraulics, horizontal lamination results from deposition of a flood couplet of paired laminae. A thin layer of sand is deposited during rising flood, then under waning flow conditions the surface becomes winnowed and "armoured" with a traction carpet of heavy and imbricated platy minerals including carbonaceous trash, which is strong enough to resist re-working by subsequent floods (Frostick and Ried, 1977). Moss (1963) also recognized steadily decelerating stream flow as a basic cause of the formation of a cohesive traction carpet of fines. It is concluded that shallow laminar flows of pulsatory or unsteady velocity similar to arid zone flash-floods were responsible for the formation of horizontally-laminated sand in the Waterval crevasse-splay lobe.

The Amandelboom crevasse-splay sandstone is interpreted as representing a geomorphologically more mature splay made up of two progradational lobes separated by a period of normal floodplain deposition. The initial splay lobe was deposited rapidly during a single flood event. It has a non-erosive base and is composed of a series of meso-form compound "bars" with intervening hollows. These are interpreted as having been deposited by semi-channelized flood discharge of sufficient depth (+/- 1.5 m) and velocity to cause sandwave migration. The "bar" forms were actually shaped during falling-water stages by emergence of the crevasse-splay surface between a network of wide shallow channels. Their shape, therefore, is erosively rather than depositionally modelled. Similar erosively-bound bars were described from interpreted splay sandstones of the Lower Beaufort by Stear (1983, 1985) and have been recorded in modern flash-flood ephemeral streams by Billi and Tacconi (1985) and Sneh (1983).

The supply of water to the crevasse channels was abruptly cut-off as water levels in the main channel dropped below the bottom of the breach. Standing water in the channels and hollows on the splay surface allowed settling-out of suspended fines. At the same time aeolian reworking of the exposed "braid" bars formed slip-faced dunes on the leeward flanks that toed into the waters edge.

During the succeeding flood event the channels were re-occupied by sediment-laden floodwaters that eroded-out much of the slack-water fines. As flow velocities waned, abundant fine sand that was being transported in turbulent suspension, was rapidly "dumped" on the channel floor in conformably bedded sand layers. These layers were immediately deformed by current shear and gravity-sliding of the channel sides towards the axis. As more sand layers accumulated, dewatering of the lower strata further deformed the sedimentary fabric. Similar deformation and dewatering structures have been recorded from modern levee/splay deposits of the Mississippi floodplain (Ray, 1976).

Eventually the erosively-bound bars were completely covered by the succeeding splay sands, effectively restoring the initial sand flat topography. Mudcracked rippled surfaces in the topmost strata indicate shallow water deposition by small flood pulses during this period of splay abandonment.

The second major unit of splay progradation was abandoned much more slowly than the first suggesting that, during its initial flood surge, the crevasse channel had incised into the bank to a point below the normal flow water-level in the main channel. This is in accordance with observations of the Mississippi crevasse-splays made by Farrell (1987).

Abandonment of the crevasse-splay was most likely caused by avulsion of the main channel in the case of Waterval Unit 1 and by downstream migration of the contributing meander in the case of the Amandelboom sandstone. In both cases they are buried by sheet flood siltstones of proximal floodplain facies.

Cross and Smith (1985) and Smith *et al.* (1989) describe similar stages in the growth of crevasse-splays on the Cumberland Marshes, Saskatchewan. Although the climatic conditions are different, morphologically and hydrodynamically, they appear to be comparable. The initial splay consists of a fan-shaped sand lobe with wedge-shaped profile and flat, non-erosive base, much like the Waterval crevasse-splay. If some of the main channel discharge is "captured" by the crevasse channel, the crevasse-splay becomes elongate. This is effected through multiple bifurcations of the channels which at the same time become incised into the vertically-accreted splay deposits. Numerous smaller splay lobes emanate from these branching channels. Towards the distal end of the splay, the channels coalesce to form a single distributary channel that turns to flow downslope parallel to the main river. These stages of splay development are envisaged for the more mature Amandelboom-type crevasse-splay sandstone.

Local small <1 m thick coarsening-upward sequences within the proximal floodplain deposits are interpreted as a reflection of steadily increasing energy conditions such as may be encountered in advance of a prograding crevasse-splay lobe (Bridge, 1984; Smith *et al.*, 1989).

The hydrodynamics responsible for accumulating the "shoestring" sandstones were, like those of the crevasse-splays, erratic and dominantly of upper-flow regime. The narrow range of palaeocurrent directions confirms that these channels were straight to slightly sinuous. The longitudinally cut undisturbed sets of tangentially-based foresets (De Celles *et al.*, 1983) in the middle of the preserved channel-fill are attributed to migrating subaqueous sandwaves (Jackson, 1976a) infilling elongate spoon-shaped scours on the channel floor (Harms *et al.*, 1963; High and Picard, 1974). The sequence above these trough cross-bedded sets is composed of ripple and ripple-drift cross-laminated sandstone deposited under decelerating velocities from flow with a high suspended load to traction load ratio (Nanson, 1980).

Low width/depth ratios of these essentially vertically-accreted channel-fill sandstones suggest that they were strongly confined by the alluvium into which the channel was initially cut. Stear (1980) and Blakely and Gubitosa (1983) describe similar sandstones of "ribbon" geometry (Friend *et al.*, 1979) that display "wings" of sandstone tapering outwards from either side of the uppermost strata. The wings are interpreted as levee sands associated with distributary (or tributary) channels.

Distributary channel sandstones of similar geometry to those of the Teekloof Formation are described by Fielding (1986) from the Durham Coal Measures. He found evidence for lateral accretion in some of the more sinuous channels but not in those that were straight or only slightly sinuous. The latter were vertically accreted and incised into the floodplain, terminating downstream in wide shallow "distal feeder channels" issuing into the floodbasin lake.

Several portions of the exhumed shoestring sandstones on the Reiersvlei surface are superimposed on one another. In this respect they resemble the "fixed" channels of Friend (1983) which are distinctive in their lack of lateral migration due to deep incision into floodplain alluvium, vertical superpositioning of channel deposits and abrupt channel switching.

Similar "shoestring" sandstones with width/depth ratios approaching one have been described from the Permian red-beds of Texas by Sander (1989). The geometry and structures of the "straight channel fills" are similar to those recorded on Leeukloof (Figs. 8 and 9). Sander attributes the stacking of sets of cross-bedding to repetitious, rapidly waning flood events and the lateral stability of these channels is explained by the erosional resistance of floodplain muds perhaps enhanced by thick bank vegetation.

Recently, Smith et. al. (1989) described similar narrow low sinuosity channels from the interchannel areas of the Cumberland Marshes, Saskatchewan where they comprise the distal distributary channels of mature crevasse-splay fans. They are formed by the coalescence of several anastomosing streams in the finer-grained distal crevasse-splay sediments where bank strengths are high enough to sustain a "fixed" channel.

The proximal floodplain facies are, therefore, regarded as distal equivalents of the levee deposits, having accumulated incrementally from the same floodwaters but under generally lower flow energies. This resulted in slightly more suspension-load deposition and less erosion of the floodplain surface. They were areally the most extensive of the inter-channel deposits, flanked by the channel-belt ridges on one side and merging basinward with lacustrine sediments. The normal sheet-flood accretion of massive silts and muds was often interrupted by both single event and prograding crevasse-splay lobes as well as incision by narrow low-sinuosity distributary channels.

2.3.5. Distal Floodbasin Facies

Distal floodbasin deposits are 0.5 to 1.5 m thick sequences of thinly bedded sandstone/mudrock couplets interbedded with sharply bounded tabular fine-grained sandstones with preserved palaeosurfaces, massive green and reddish brown mudstone and rare laterally discontinuous beds of highly silicified microlaminated mudrocks.

In stratigraphic sections these sequences are most commonly encountered in the middle and upper parts of the interchannel unit, usually bounded by proximal floodplain deposits (see Appendix Figs. 8, 9, 11, 12, 17 & 18) and often abruptly terminated by the base of a crevasse-splay sandstone.

Mudrock colours are generally darker than in the proximal floodplain deposits and the alternation between dark bluish-grey, greenish-grey and dark reddish-brown colours is more common. This appears to be texturally controlled. Mottling, commonly involving green and maroon tints, is not restricted by lithological boundaries.

The rapidly alternating sandstone/mudrock couplets are commonly capped with oscillation rippled siltstones and a mudstone veneer. In parts of the sequence, especially towards the top, they generally contain sand-filled polygonal desiccation cracks (Fig. 39) and polygonal networks of "knobbly" textured calcareous nodular material. Some of the mudcracks widen towards the top into a funnel shape. Clean fine-grained sandstone filling mudcracks is rarely in continuity with an overlying bed and sometimes tapers downwards into "knobbly" textured calcareous nodular material (Appendix Fig. 11).

Distinctive massive mudstone beds with a needle-weathering pattern do occur rarely in these deposits. They range from green to maroon in colour and often contain impressions of plant stems (*Schizoneura*), leaves (*Glossopteris*) and leaf whorls (*Phyllotheca*) and horizons of rosette-shaped clusters of quartz pseudomorphs after gypsum. True "desert rose" gypsum clusters are also

FIG. 39 Aeolian sand-filled desiccation cracks in distal floodbasin deposits exposed on the Leeu River bed at metre 1,200 of Appendix Fig. 6.

FIG. 40 One of a number of distal crevasse-splay sandstones exposed in the Leeu River bed at the *Diictodon* trackway locality on Waterval (see Appendix Fig. 20). These sandstones are characterised by a sharp basal contact followed by near horizontal lamination that in some cases has been convoluted over large areas. This passes upwards into climbing ripple cross-lamination, ripple cross-lamination and topped by an adhesion rippled, "warty" or "matted" mudstone-veneered surface on which reptile tracks are preserved.

encountered with massive greenish silty-sandstone beds in this facies. Calcareous nodules are generally absent although small oblate siliceous nodules with a distinctive outer crust and internal septarian shrinkage cracks do occur in this facies. Therapsid body fossils are generally very scarce in these deposits. Those that are found are usually isolated skulls and post-cranial elements, highly compressed and rarely peri-mineralized. Amphibian remains (*Rhinesuchus*) show a much higher degree of articulation and appear to be relatively more abundant than therapsids in these strata.

Two distinctive lithologies are interbedded with the thinly bedded mudrocks of the distal floodbasin facies. They are a tabular sandstone and a highly silicified microlaminated mudrock. These are interpreted as distal crevasse-splay and offshore rhythmites respectively and are treated as subfacies of the distal floodbasin deposits.

2.3.5.1. Distal crevasse-splay subfacies

This subfacies is made up of tabular, sharply bounded fine-grained sandstone beds up to 30 cm thick with distinctive smooth mudstone-veneered upper surfaces. Internally the sandstone shows structures resembling a truncated Bouma-sequence that is characteristic of turbidites (see Fig. 40). Above a sharp flat or slighly undulating basal contact the following sequences are recorded: near-horizontal laminations convoluted in places; climbing ripple cross-lamination; ripple cross-lamination; adhesion rippled, "warty" or matted surfaces; mudstone veneers.

In river bed exposures near the Waterval farmhouse in Study area 2, two sets of therapsid footprints are preserved on the top of a distal crevasse-splay sandstone (Figs. 41 and 42). The size, pace length and width of the larger pentdactyl trackway is attributed to the small quadrapedal dicynodont, *Diictodon*. A close-up of this surface, illustrating the matted surface textures, is shown in figure 42.

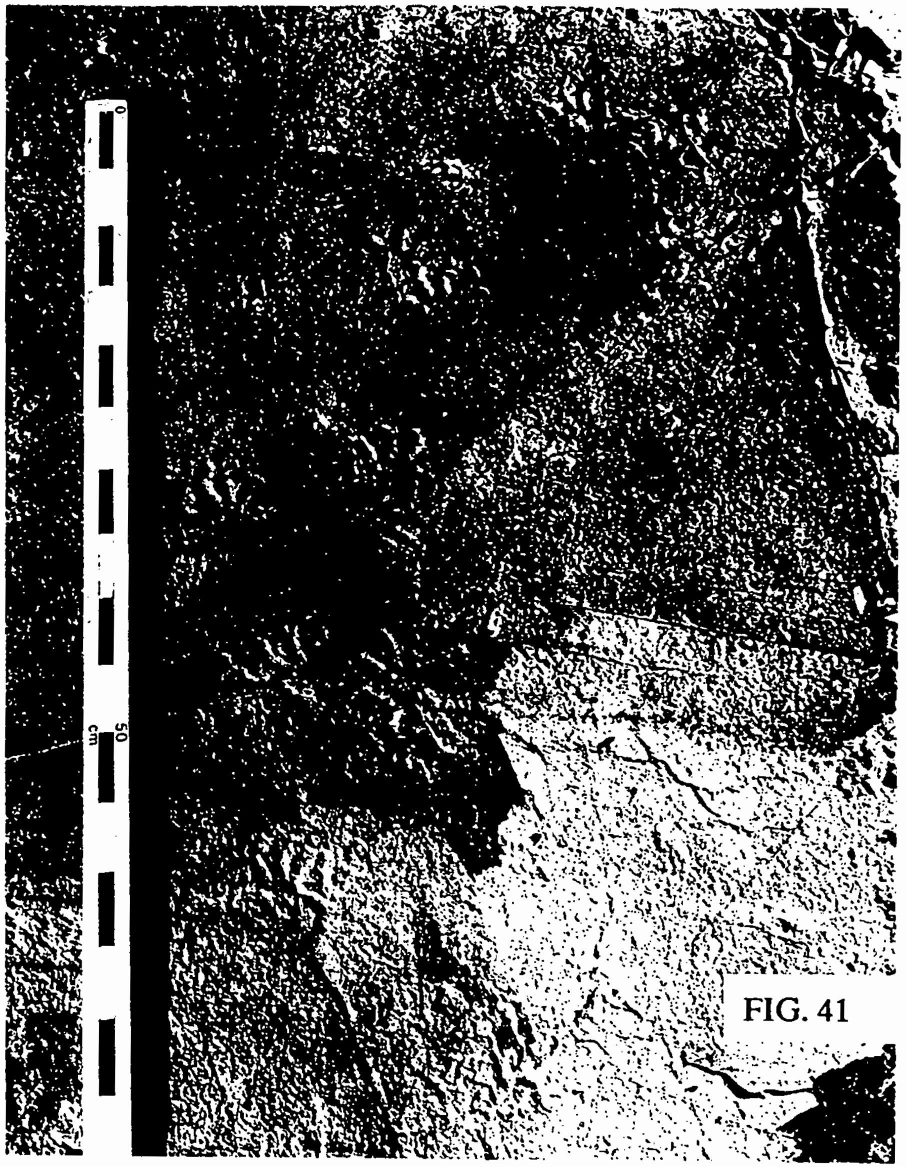


FIG. 41

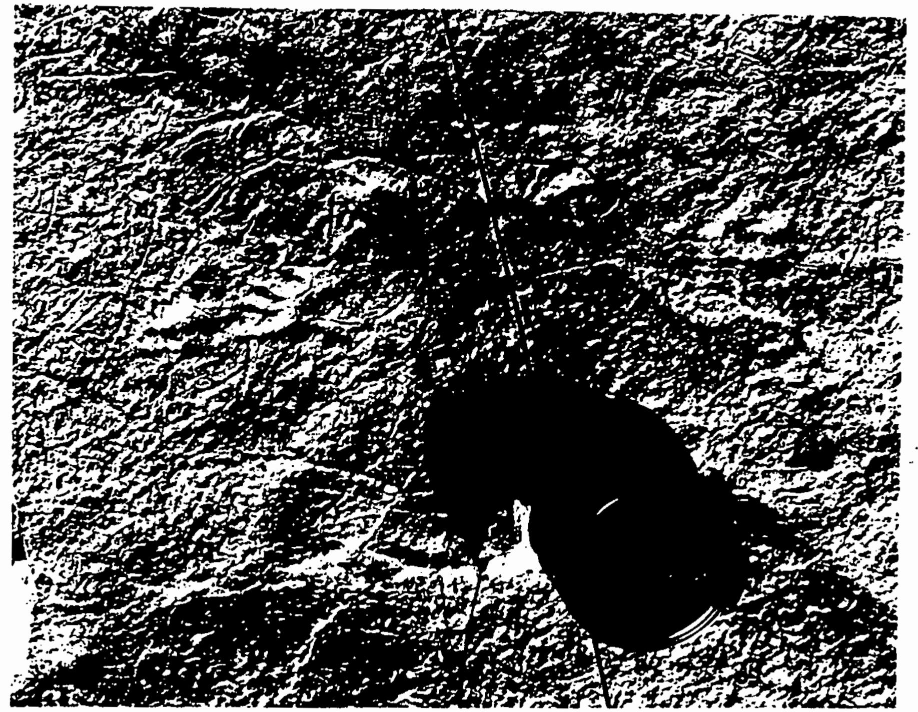


FIG. 42 Close-up of the trackway surface in figure 41 illustrating the "matted" surface texture and a set of smaller footprints possibly preserved as underprints beneath an algal mat.

Diictodon trackway preserved on the upper surface of a distal crevasse-splay sandstone exposed in the Leeu River bed on Waterval (see Appendix Fig. 20). The partial overlap of pes onto manus prints and the inward "drag" of the digits suggests that *Diictodon* had a "swaggering" gait and slightly rotated its feet on the ground as it was walking.

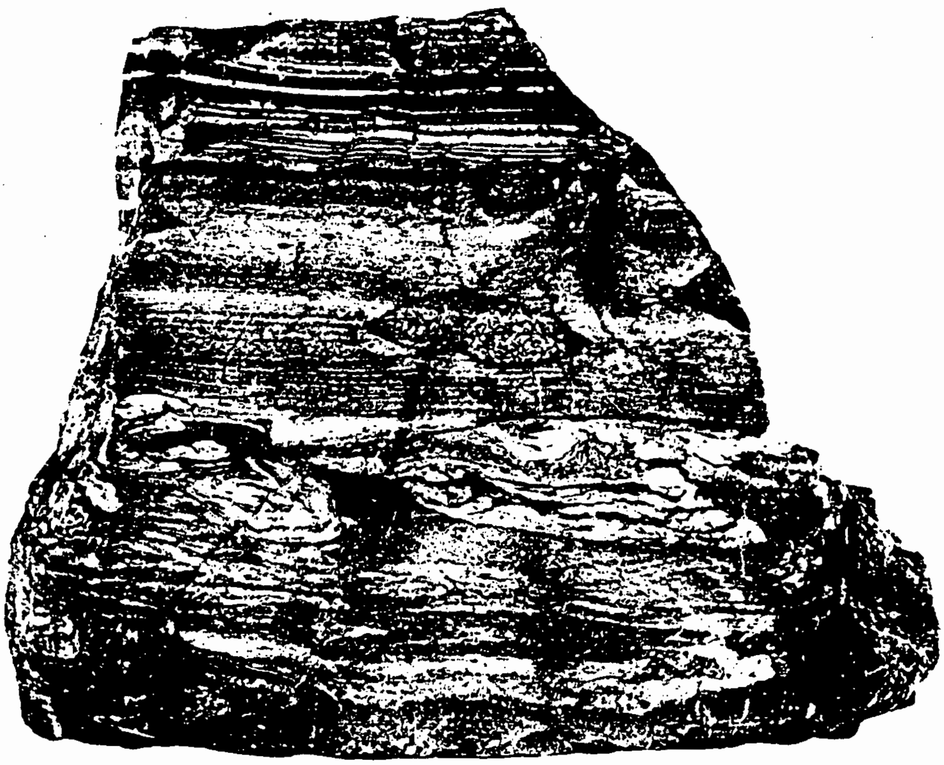


FIG. 43 Complete section of a "chert band" from distal floodbasin facies of the Teekloof Formation displaying varve-like microlaminations convoluted in places and slight compressed burrows.

2.3.5.2. Offshore lake subfacies

This facies comprises thin laterally discontinuous beds of highly silicified cream-coloured microlaminated mudrocks up to 15 cm thick. They are encountered rarely in the Teekloof Formation. In the Abrahamskraal Formation, however, these so called "cherts" are much more common and more laterally extensive, outcropping for tens of kilometres (Roussouw and De Villiers, 1952).

Figure 43 shows the sedimentary characteristics of one of the silicified siltstones that outcrops on the farm Wittehart, near Study Area 3. They commonly display continuous horizontal and crinkled microlaminations, flasar and lenticular bedding, convoluted laminae and micro-faulting. Isolated vertical burrows occur in these beds filled with overlying siltstone with some brecciated fragments of the laminated mudstone. Many have circular, funnel-shaped openings onto the upper surface of the silicified bed suggesting that this was a hiatus surface.

The upper surface is characteristically "hummocky" with a pitted surface texture and patches of scattered fish scales and bones. The pitted texture is imparted by the removal of small elongate dark-brown crystals identified by Martini (1974) and Ho Tun (1979) as volcanic glass shards. The lower contact is less clearly defined being transitional with the underlying distal floodbasin mudrocks.

2.3.6. Hydrodynamic Interpretation of Distal Floodbasin Facies

The sandstone/mudrock couplet that makes up the basic accretion unit of these deposits is interpreted as having been deposited during a single flood event that injected a plume of sediment into the margin of a freshwater lake. Similar textural couplets are recorded in closed arid-zone lakes in Sudan (Sneh, 1983) and western Australia (Alderman and Skinner, 1957) and are attributed to rapid sedimentation of sand from subaqueous low-density turbidity plumes followed by extended periods of steady suspension settling of silts and clay-rich fines. Periodic exposure of the marginal lake floor is evidenced in the sand-filled polygonal mudcracks that often disrupt these flood couplets. The fact that the mudrocks become more abundant towards the top of the distal floodbasin sequences is indicative of a change from perennial to ephemeral lake conditions (Demicco and Kordesh, 1986).

During overbank events most of the coarser sediment load that reached the floodbasin lakes probably issued from the mouths of distributary channels and distal crevasse-splay networks (Pizzuto, 1987). The thicker, smooth and ripple-topped, sandstone beds with poorly-developed Bouma-type sedimentary sequences are interpreted as distal crevasse-splay lobes deposited episodically as a single flood unit from sediment-laden low density hyperpycnal flows along the floor of a shallow freshwater lake (Mutti and Ricci Lucci, 1975; Walker, 1965). The presence of adhesion ripples, algal matted surfaces and therapsid footprints on these sandstones suggests a shallow water, marginal lacustrine setting (Lockley, 1986; Van Dijk, 1978). Similar surfaces have been described from several other localities in the Lower Beaufort. Some show evidence of emergence and desiccation (De Beer, 1987; Stear, 1978) whereas others were buried without ever being exposed (Smith, 1987).

The vertical stacking of several of the turbidite sandstones separated by thin veneers of clay-rich fines is an indication of episodic surges in sediment supply which is characteristic of ephemeral stream discharge in semi-arid terrains (Williams, 1971; Rust, 1981). The high preservation potential of palaeosurfaces on the upper surfaces of these turbiditic sands is probably due to the synchronous expansion of the lake margins as overbank floodwaters collected in the axial floodbasin lake. Thus in effect, the lake margin rapidly transgressed over the prograding sandy distal feeder channels and crevasse-splay lobes (draping them with a veneer of fines).

The fissile green mudstone beds that commonly overlie and preserve distal crevasse-splay palaeosurfaces are interpreted as clay-rich fines that were deposited from suspension during the period of lake high stand following a major flood event. Much of these suspended fines entered the lake during overbank flooding of the main channels. However, this would have been supplemented by local run-off around the lake margins during downpours as well as by an aeolian influx.

The lack of bioturbation and the preservation of abundant plant material in the non-laminated colloidal muds suggests that, at times, salinities were high enough to prevent infaunal colonization and retard bacterial decomposition of organic matter. Radiating "rosette" -shaped pseudomorphs of gypsum (Stear, 1978), or possibly trona (Demicco and Kordesh, 1986) that are found in these mudstones are an indication of penecontemporaneous evaporite precipitation. Distinctive "desert rose" crystal habits of some of the quartz pseudomorphs after gypsum that are found in greenish-grey silty sandstone beds of this facies were interpreted by Keyser (1966) as an indication of an arid climate. This conclusion is supported by recent studies of gypsum crystallization by Cody and Cody (1988) who found that such clusters of crystals were only formed under high temperatures in the presence of organic colloids. Such conditions may be produced in marginal areas of a semi-arid floodplain lake that is periodically replenished by streams flowing off a well-vegetated meanderbelt ridge.

Perennial sedimentation in the deeper water, offshore parts of the lake is indicated by the very finely laminated siliceous mudrocks. In these beds, the common association of varve-like light/dark laminae with convoluted horizons suggests that they accumulated largely by pelagic sedimentation possibly through a thermally stratified water column with a seasonal overprint. Deformation of parts of these sequences may have been caused by current shear on the lake bottom following the breakdown or "overturn" (Beadle, 1974) of stratification during winter storms. Similar light/dark microlaminations occur in bottom sediments of modern shallow semi-arid lakes in western Australia. They are caused by seasonal alternation of light coloured, carbonate-rich summer muds with darker, carbonate-poor winter muds (Alderman and Skinner, 1957).

Carbonate precipitation, in this case, is in response to increased pH of the lake water brought about by the de-oxygenating effect of algal blooms and plant growth during early summer combined with a gradual shrinkage of the lake due to evaporation. The structures and facies relationships of the so-called "cherts" in the Lower Beaufort are attributed to mainly pelagic deposition in the offshore areas of perennial floodbasin lakes that were subject to annual fluctuations in lake level and carbonate solubility imparting a seasonal overprint of carbonate precipitation in the bottom muds. The preservation of the microlaminae in the Teekloof offshore deposits may have been enhanced by cohesiveness imparted by carbonate flocculation of suspended clays or possibly the growth of algal mats (Carozzi, 1962) and/or bacterial slimes (McCall and Tevesz, 1982). Burrowing infauna caused minimal laminae destruction being mainly vertical-tube living organisms.

The preferential silicification of micro-laminated mudrock sequences is possibly due to the alteration, by freshwater leaching, of volcanic glass shards (Martini, 1974; Ho Tun, 1979) that had concentrated in these sediments during a long period of very slow sediment accretion. Weathering of the pyroclastic glass probably occurred during early diagenesis (Surdam and Eugster, 1976) releasing silica that preferentially replaced the more porous carbonate laminae in the enclosing sediments.

Sedimentary sequences similar to Teekloof Formation distal floodbasin deposits have been described from several fluvio-lacustrine successions all of which have been interpreted as having undergone various degrees of desiccation. These include: Triassic limestones and cherts of playa origin from the East Berlin Formation of North Carolina (Wheeler and Textoris, 1978; Sanders, 1968); marginal lacustrine mudflats of the Green River Formation (Surdam and Wolfbauer, 1975; Eugster and Surdam, 1973; Smoot, 1978); algal laminated carbonates of lacustrine origin from the Pliocene Ridge Route Formation, California (Link, Osborne and Armile, 1978); the Triassic of Greenland (Clemmensen, 1978).

To summarize, the distal floodbasin facies were deposited in permanent and ephemeral axial floodbasin lakes mostly by episodic, flood generated turbidity currents that interrupted the steady slow settling of suspended fines. Periodic, possibly annual, shrinking and expansion of the lake margins exposed wide playa-type mud and sand flats where desiccation and evaporative pumping led to surficial precipitation of carbonate and gypsum. Sedimentation in the offshore areas of more permanent lakes resulted in varve-like laminations possibly caused by seasonal precipitation of carbonate.

3. ALLUVIAL PALAEOSOLS OF THE TEEKLOOF FORMATION

3.1. INTRODUCTION

A palaeosol is a buried landscape of the past that is no longer undergoing pedogenic modification. Under natural conditions, a soil may be effectively "abandoned" after rapid accumulation of a layer of sediment on its surface that is thick enough to change the level at which the various pedological processes operate. The thickness of sediment required to effect the removal of pedogenesis from a soil probably varies with climate but is estimated to be in the order of several decimetres. It follows that soils formed on aggrading floodplains are much more likely to be buried than those on degrading pediplains. Thus palaeosols may be expected to be commonly preserved in ancient floodplain rocks. Overbank sequences of the Eocene Willwood Formation are described by Kraus and Bown (1982) as "a succession of stacked paleosols" reflecting their abundance in the stratigraphic record.

Floodplains are not uniform sedimentary environments, since differences in accretion rates, topography and vegetation ensure that alluvial palaeosols are heterogeneous. The potential for soil formation and burial at any floodplain site ultimately depends on the time interval between overbank flood events and on the net sediment accumulation after each flood. If the flood sediment accumulation increment is small, and the periodicity of flooding is low, it is possible that the top 'A' horizon in the soil profile will incorporate the extra material without affecting the lower solum (Leeder, 1975). In this way the alluvial soil effectively absorbs small flood increments and is able to reach an advanced stage of maturity. If the periodicity of inundation is frequent and the accumulation sediment rate is high, then although the burial mechanism for preserving the soil is present, the time interval between flood events may not be long enough for recognizable pedogenic modification of the alluvium to develop. Thus, both spatially and temporally, the differential rates of pedogenesis versus floodplain accretion result in a variety of palaeosol types in different stages of maturity from the most immature Entisols to more mature Calcic Vertisols and Hydromorphic Gleys with well-developed duripan horizons.

To this suite of soil types may be added the more locally distributed palaeosols that occupied floodplain depressions and were influenced throughout their genesis by a high water-table. These palaeosols show the cumulative effects of the initial superimposition of lower upon upper horizons, and secondly, as aggradation continues, the passage of the entire profile into the saturated zone. The latter effect has been termed accumulative hydromorphy (Bown and Kraus, 1987) and is an important factor to consider when comparing ancient palaeosols with modern or recent palaeosols that have not been subjected to an extended period of continuous saturation.

It is only relatively recently that the differences between cumulative alluvial palaeosols and single palaeosols marking long term non-depositional or hiatus surfaces, has been clarified. This distinction has led to renewed interest in alluvial palaeosols as indicators of geomorphology (Allen, 1974b; Leeder, 1976), floodplain accretion rates (Allen, 1974a, b; Leeder, 1975; Bown and Kraus, 1981a; Atkinson, 1986), migration behaviour of the main channels (Allen, 1978; Bridge and Leeder, 1979; Retallack, 1986), time-equivalent floodplain sedimentation (Behrensmeyer and Tauxe, 1982; Kraus and Bown, 1986) and time resolution of palaeosol-hosted vertebrate fossil assemblages (Bown and Kraus, 1981b; Behrensmeyer, 1982; Retallack, 1984). The palaeoclimatic interpretation of palaeosols has been enhanced by detailed descriptions of micro-root channels (McSweeney and Fastovsky, 1987; Fastovsky and McSweeney, 1987), palaeovertisols (Blodgett, 1985; Sigles and Reinhardt, 1988) and through numerous studies of palaeopedogenic carbonates (Friend and Moody-Stuart, 1970; Steel, 1974; Hubert, 1978; McPherson, 1979; Wright, 1982; Prather, 1985; Allen, 1986). Furthermore, elaborate landscape reconstructions have been made from the integrated palaeoecological and sedimentological studies of Eocene palaeosols (Retallack, 1977a, b, 1981a, b, 1983).

Calcareous nodules are common in Lower Beaufort mudrocks of the southwestern Karoo and have been interpreted by several workers as of pedogenic origin and reflecting semi-arid climatic conditions on the ancient floodplains (Hotton, 1967; McPherson and Germs, 1979; Smith, 1980, 1987a). To date, there are no published descriptions of these palaeosol profiles, nor has any attempt been made to record their distribution in relation to the various floodplain facies. The purpose of this investigation is to describe the palaeosols from the various fluvial facies and interpret the controls of pedogenesis in different parts of the ancient floodplains.

3.2. PALAEOSOL PROFILES OF THE INTERCHANNEL FACIES ASSOCIATION

Three depositional facies and six subfacies have been defined within the voluminous overbank or interchannel sequences of the Teekloof Formation. Fundamental to this facies distinction is the decreasing periodicity and competence of flow across the floodplain surface with increasing distance from the main channel. The three main depositional environments of the interchannel belt included levee/channel bank, proximal floodplain and distal floodbasin deposits.

Three main types of palaeosol profile have been identified within the Teekloof Formation of the southwestern Karoo. They repeatedly occur within specific sedimentary facies described previously and as such they are interpreted as having accumulated on different parts of the ancient floodbasin (Fig. 44). The profiles described below are fully developed examples of the three soil types, although there are many intervals that do not display the complete profile differentiation but show enough to allocate it to one of the three types. Many outcrops also contain well-developed hydromorphic colour mottling. True hydromorphic soils and hydromorphic "overprints" are not bound to any specific facies and are fairly common throughout the interchannel sequences.

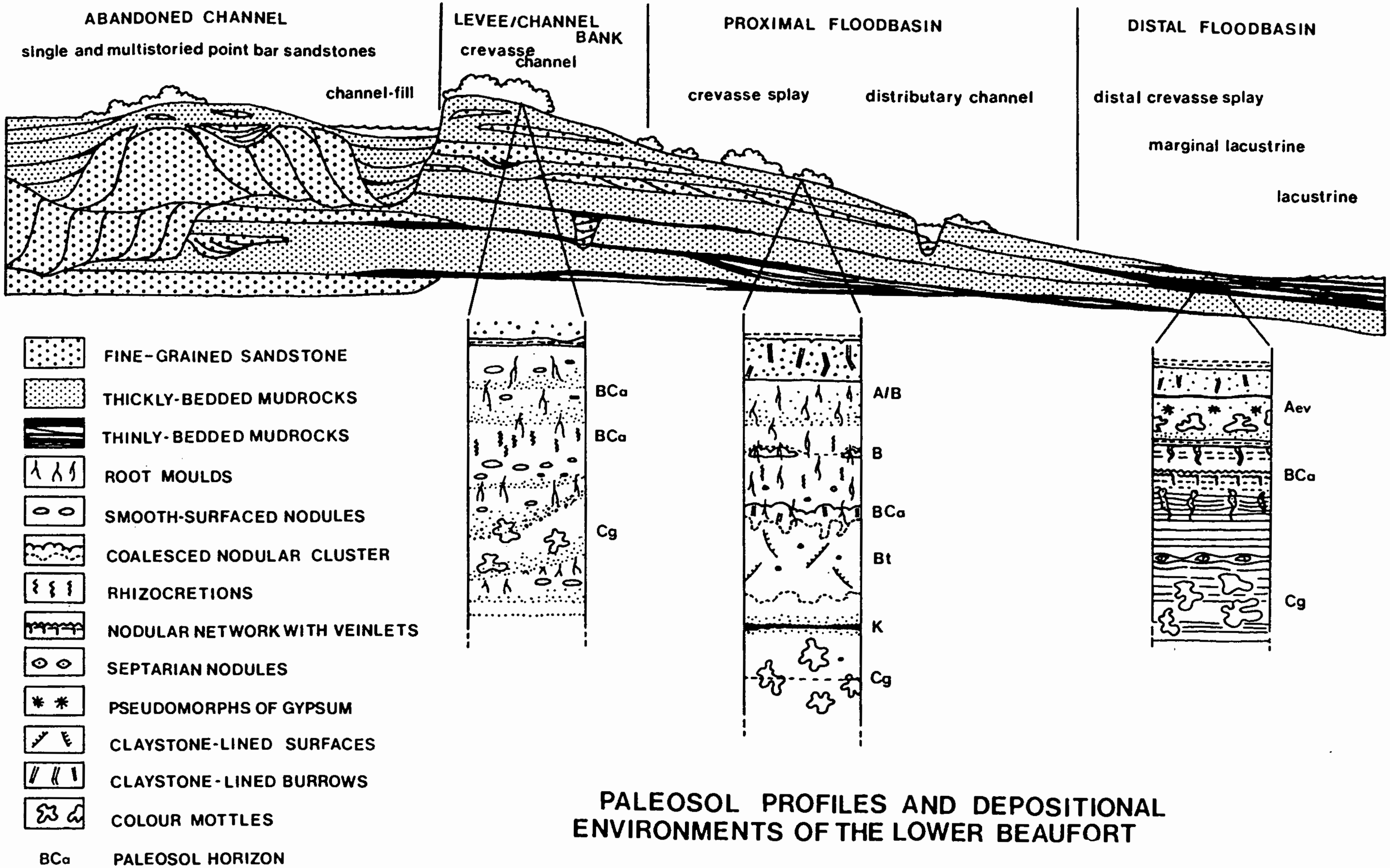


FIG. 44 Generalized cross-section of a Lower Beaufort floodplain showing the various depositional environments with their major sediment packages and palaeosol profiles. BCa = Calcareous B horizon, Cg = Gleyed C horizon, Bt = Textural B horizon, K = Calcareous duripan layer, Aev = Evaporitic A horizon.

Non-pedogenic diagenesis of the Lower Beaufort strata in certain areas reached lower greenschist phase (300 degrees C, Martini, 1974) but over much of the southwestern Karoo it is of lower grade. The most pervasive diagenetic "overprints" include silicification of the sediments, especially carbonate replacement and quartz overgrowths on detrital grains. Because the varying grades of diagenesis at different stratigraphic levels in different parts of the basin have affected the mudrock colours and chemistry, these criteria are not considered reliable for recognising palaeosols and are, therefore, used reservedly in the following descriptions.

3.2.1. Levee/Channel-Bank Palaeosols

Palaeosols of the levee facies are characteristically drab coloured, predominantly greys and greens and mottled horizons with a paucity of reddish-browns and purples. They contain abundant sub-vertical burrows and/or root channels, which are especially visible in the thin buff-coloured sandstone lenses. Some rooted horizons contain abundant vertically orientated rhizocretions (Klappa, 1980; Fig. 45) composed of solid micrite cylinders with a characteristic rough surface texture.

Smooth-surfaced calcareous glaebules occur within the lower levels of these palaeosols. Horizons of these nodules, in the order of 30 cm thick, are laterally continuous for up to 100 m. The nodules are oblate, varying in length from a few millimetres to 25 cm, but most common in the 5 to 10 cm size range. Smaller nodules tend toward higher sphericity, larger ones are more irregular and appear to have been formed by the amalgamation of several smaller nodules.

The external colouration of the glaebules usually matches that of the enclosing mudrock, commonly greenish-grey siltstone. Internally, the nodules consist of grey micrite with rare fissures, cavities, and host rock inclusions. Commonly, they

FIG. 47 Partially prepared *Pristerodon* skull from within a smooth-surfaced nodule. Note the "fissured" bone surface caused by displacive growth of calcite between cracks and cranial sutures. Scale bar = 1 cm.

FIG. 45 Top: four calcareous rhizocretions representative of a large collection made from a levee palaeosol on Reiersvlei.
Bottom: four similar rhizocretions collected from modern dune deposits at Elandsfontein on the Cape West Coast.

FIG. 46 In situ *Diictodon* skull plus lower jaw and some caudal vertebrae lying dorsal-up with snout towards the right. The fossil is completely perimineralised with smooth-surfaced nodular material. Broken surface shows the thickness of the calcareous nodule around the bone and the "crazed" texture of the bone surface.

FIG. 47

FIG. 45

FIG. 46

contain fossil vertebrate bones and in many cases the glaebule shape matches that of the the enclosed bone, (Fig. 46). Displacive crystallization of these nodules is evidenced in the "explosion" of perimineralized skulls where nodular material appears to have forced apart the sutured dermal bones (Fig. 47).

3.2.1.1. Interpretation

Palaeosols in the levee deposits are poorly horizonated, reflecting a relatively immature soil (Fig. 44). They consist of poorly defined drab grey 'A' horizons, with claystone-lined burrows and root casts, passing downwards into a calcic upper 'B' horizon. This overlies mottled, but otherwise unaltered, parent alluvium which contains scattered calcareous glaebules. Colour layering in this 'C' horizon reflects primary textural alternations, the sandier deposits being greenish, and siltier deposits tending toward dark grey.

The sedimentary sequences and structures resemble those of modern levee deposits described from semi-arid alluvial plains (Butler, 1958; McKee *et al.*, 1967; Singh, 1972). The ridge-like topography, the paucity of clay, and generally coarser textures of the Teekloof levees would have promoted rapid infiltration of moisture through the surficial sediments. Following a major overbank flood event the newly deposited sediments would soon have been colonized by burrowing invertebrates and by pioneer plants. As vegetation diversity and density increased so would the translocation of carbonate from the surficial to the lower solum which was initially preferentially precipitated around roots. With increasing maturity, carbonate precipitation apparently became more concentrated within a narrow calcic horizon at the base of the root zone.

The glaebules in the lower solum of the Teekloof levee palaeosols are distinctive in their smooth surface textures and it is possible that they were actually precipitated at the groundwater interface and that their surface textures reflect this generally wetter environment (Semeniuk and Megher, 1981). The narrow horizons of rhizocretions are indicative of the early precipitation of calcium carbonate around roots in the porous, well-aerated upper solum (Klappa, 1980; Semeniuk and Searle, 1985).

Proof that some, if not all, the carbonate glaebules had consolidated earlier than their host alluvium is indicated by their common inclusion in mudstone pebble-lag conglomerates that line the thalweg scours of major channel sandstones. These nodules were most probably derived from the soils contained in blocks of bank material that collapsed from the cut-bank.

Butler (1958) has recorded abundant lime glaebules some 60 - 70 cm below the levee surfaces of abandoned Pleistocene semi-arid river systems in southeast Australia. He attributes the lack of textural distinction between the A and B horizons in these entisols to the presence of lime and its effect of lowering the plasticity of clays. He also highlighted the abundance of lime in the levees compared to the streambed and axial floodbasin areas. A similar general distribution of carbonate is found in the Lower Beaufort floodplain palaeosols.

Periodic, possibly seasonal, scour and sedimentation on the levee surfaces appears to have prevented the pedological processes from operating long enough, on any portion of the parent alluvium, for horizons to become texturally distinct. Thus, the immature nature of the levee palaeosols in the Teekloof Formation is mainly attributed to their proximity to a river that was subject to overbank flooding.

3.2.2. Proximal Floodplain Palaeosols

Palaeosols in the proximal floodplain deposits of the Teekloof Formation are characterized firstly by the abundance and variety of calcareous glaebule shapes and accretionary layers and by the presence of dense, dark reddish-brown, slickensided siltsone horizons (Fig. 44). Mudrock colours are more variable than the levee deposits with more reddish-brown, brown and mottled purple horizons. Colour banding is, however, still predominantly controlled by the sedimentary fabric, the exception being the clay-rich dark reddish-brown siltstone which contains numerous sub-vertical planar surfaces coated with slickensided reddish-brown claystone skins (Figs. 48 and 49). This structure imparts a distinctively crumbly weathering pattern as opposed to the blocky texture of unaffected siltstones. These surfaces resemble the arcuate "skew planes" described by Brewer (1964) and are interpreted as stress argillans brought about by shrinking and swelling in response to wet/dry oscillations in the lower solum of a calcic vertisol. In many cases the well-developed textural 'B' horizons are overlain by a single layer of large brown-weathering calcareous nodules (Fig. 48) which are similar in geometry and texture to palustrine carbonates described by Freyet and Plaziat (1982) and Calvo *et al.* (1989).

Horizons of calcareous nodules and solid layers of nodular material are common in the proximal floodbasin sequences. Unlike the smooth oblate levee nodules these have an irregular, knobbly appearance, as if formed by the accretion of numerous small glaebules. They occur in "clumps" up to 5 m in diameter and 10 cm thick which in some cases interconnect to form, in plan view, a "sheet with holes" (Fig. 50). When fully developed, these clumps have a sharp, distinctly hummocky upper surface and a gradational lower contact. The lower half of the micritic mass usually contains angular fragments of the host mudrocks which gradually decrease in size and number upwards, leaving the upper half devoid of intraclasts (Fig. 51). Vertical, claystone-lined burrows or root channels are visible in broken nodules (Fig. 51). Polished thin sections of these nodules reveal numerous rootlet channels surrounded with green reduction haloes and partially filled with an opaque, possibly carbonaceous, material (Fig. 52). Black cubic crystals and diffuse zones of haematite enrichment, were identified in many of the nodules. Some contain drusy quartz-lined star-shaped cavitites or arcuate fissures, the larger of which are filled with equant calcite and amorphous manganese oxide crystals.

Accretionary sheets of nodular material are rarely thicker than 5 cm, sometimes thinning to a few millimetres, but their resistance to weathering causes them to crop-out as continuous ledges (Fig. 53) that can be followed for several

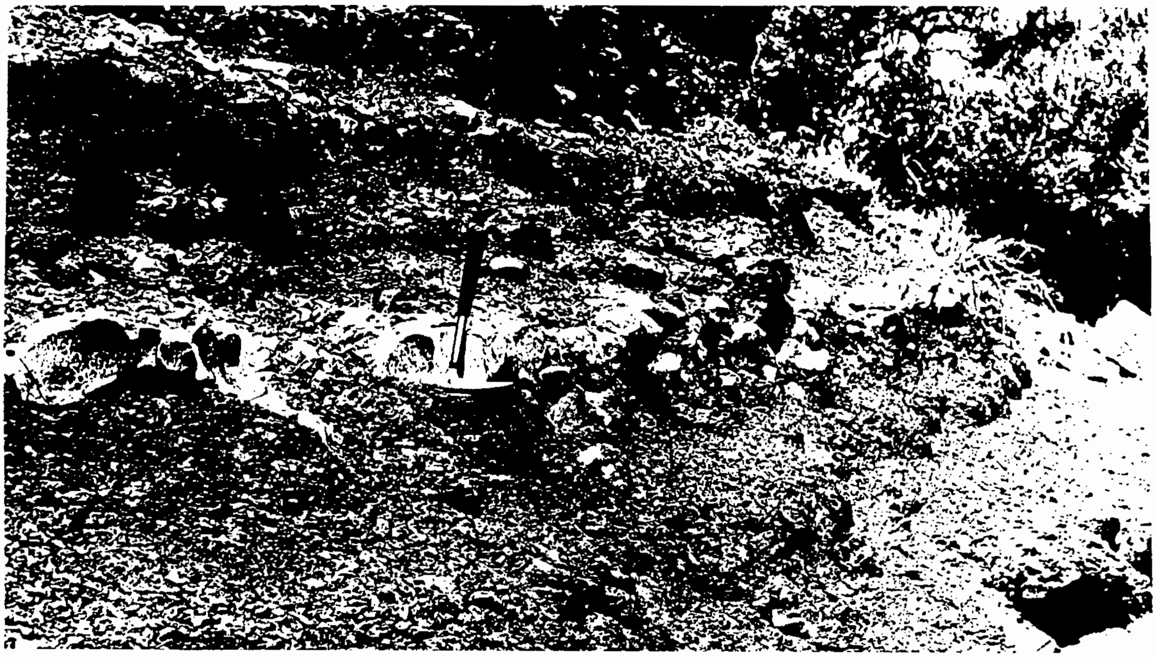


FIG. 48 Prominent calcic B horizon (at hammer-head) of a proximal floodplain palaeosol on Bergvallei (Appendix Fig. 20). The crumb weathering texture in the mudrocks immediately below the BCa horizon is imparted by an illuvial accumulation of clay argillans (Fig. 49).

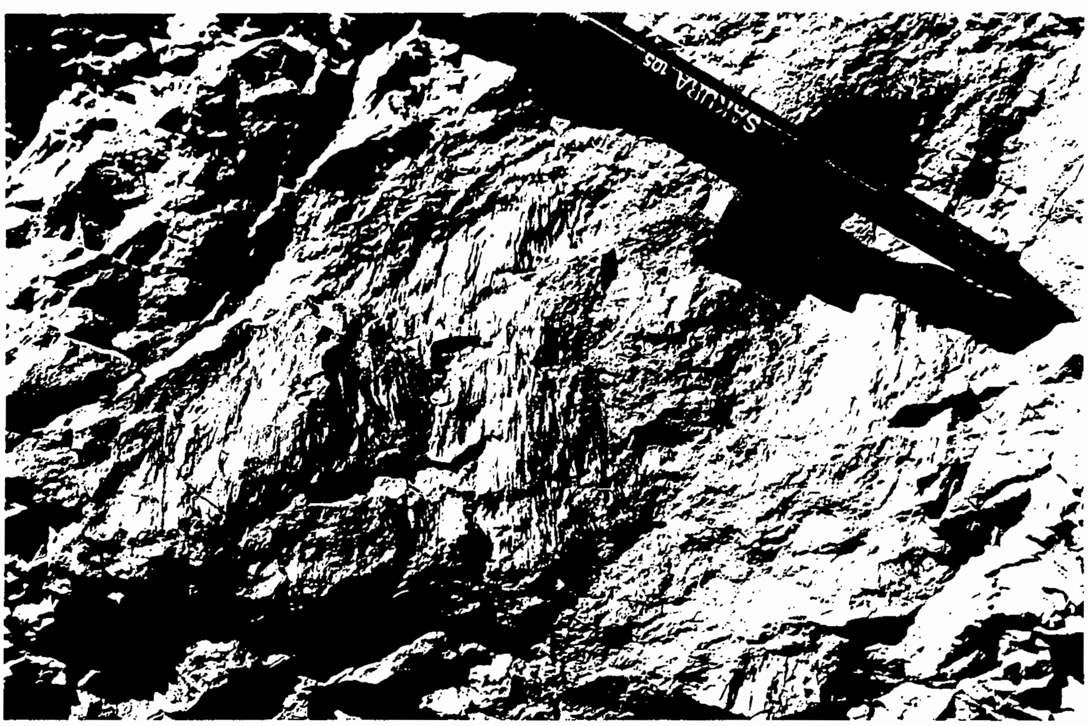


FIG. 49 Close-up of a slickensided claystone draped "skew plane" (Brewer, 1964) in the illuvial Bt horizon below the hammer head of Fig. 48. (See Appendix Fig. 20).

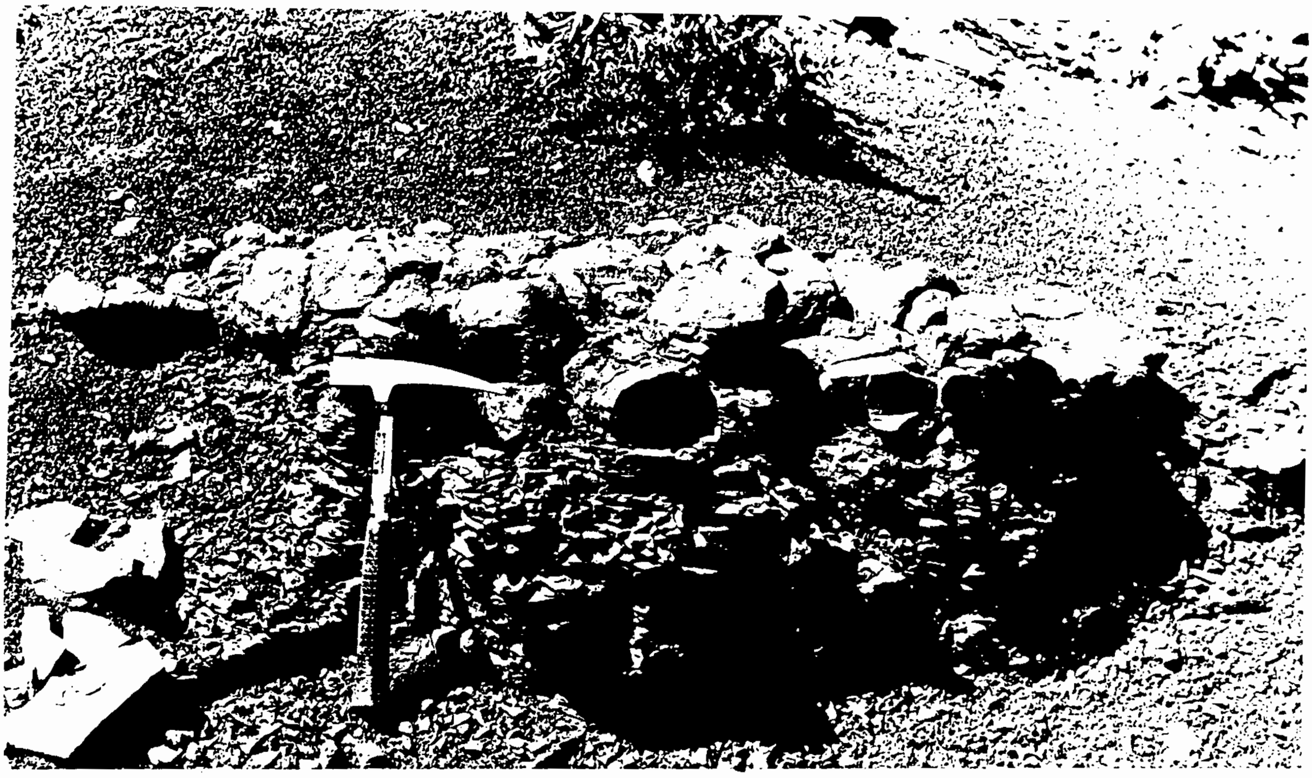


FIG. 50 Cluster of smooth-topped brown-weathering calcareous nodules in a proximal floodplain palaeosol on Amandelboom (Appendix Fig. 20).

FIG. 51 Close-up of in situ proximal floodplain calcareous nodule cluster showing smooth top, gradational base and vertical clay-lined root tubules. Scale in cm.

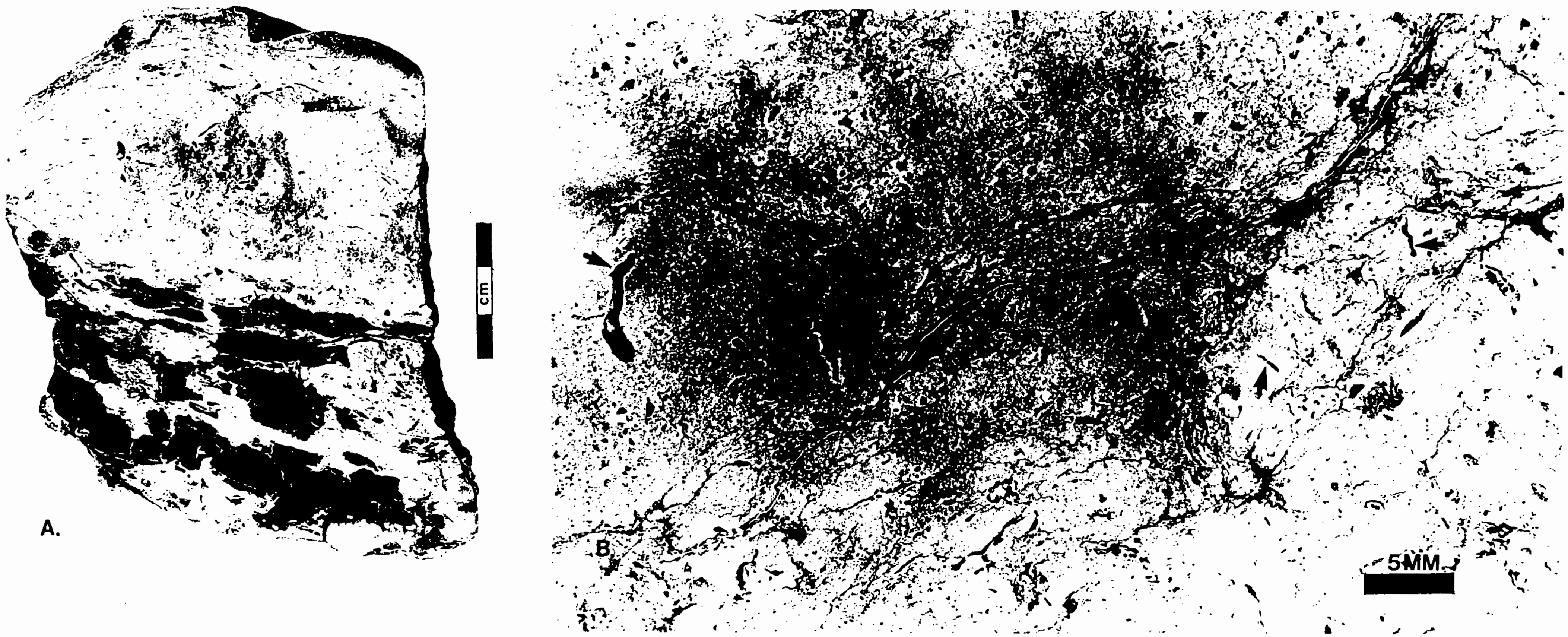


FIG. 52 Polished slab (A) and thin section photo micrograph (B) of the nodule shown in Fig. 51. Note the distinctive brecciation of mudrocks at the base of the nodule and the mudrock-poor upper zone. Note too, the root and rootlet channels that ramify the micritic groundmass of the upper zone shown in the thin section B.

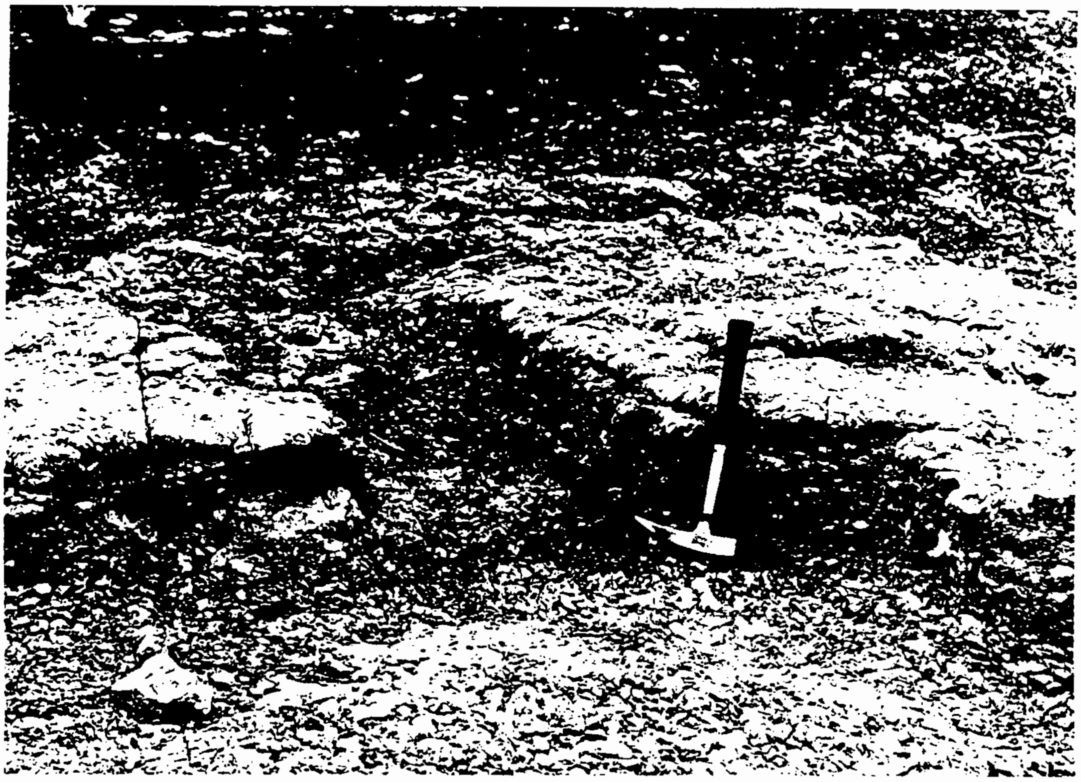


FIG. 53 Continuous accretionary sheet of palaeocaliche, possibly formed in the zone of capilliary rise just above the groundwater table in proximal floodplain areas.

FIG. 54 Selection of coprolites from Teekloof palaeosols. The cylindrical type commonly contain therapsid bone fragments and were probably produced by therapsid carnivores. The spherical types have pinch marks similar to those made by some modern ruminant herbivores. The flattened type containing masticated bone is probably a carnivore regurgitate.

kilometres (Smith, 1981). The upper surfaces are sharp and flat, with a pustular or pitted texture. The lower boundary is irregular and gradational, weathering into a series of vertical "pillars" of cemented siltstone. Internally, these "sheets-with-holes" have a dense grey micritic groundmass, similar to the glaebules, but lacking intraclasts, burrows and rootlets.

Rhizocretions occur within some of the proximal floodbasin palaeosols but are not as abundant as in the levee deposits. Calcified coprolites of bone-ingesting carnivores (Fig. 54) and calcretized therapsid burrow casts are other minor components of these palaeosols (Smith, 1987b). Colour mottling is pervasive, involving mixtures of maroon and green tints. The mottles do not appear to be controlled by sedimentary fabric and commonly transgress textural boundaries. They occur throughout the profile but are best developed in the lower 'B' and 'C' horizons of the more calcic palaeosols.

3.2.2.1. Interpretation

Near-channel floodplains were topographically level or sloping slightly downward towards the axis of the floodbasin (Fig. 44). Subdued undulations influenced the drainage properties of the soils in that the floors of depressions may have been saturated during periods of high rainfall. The abundance of fibrous rooted horizons shows that vegetation was present although the component species are not known. The presence of claystone linings to invertebrate burrows and root moulds suggests that they provided pathways for downward percolating flood waters and meteoric waters which translocated eluvial clay.

Reduced periodicity and intensity of flooding in these parts of the floodplain allowed soil-forming processes to alter the surficial alluvium for long periods before burial. During these extended periods of very slow deposition or non-deposition, mummified, weathered and disarticulated therapsid skeletons naturally accumulated on the floodplain surface along with numerous abandoned underground burrows. Occasional catastrophic flood events scattered smaller bones, buried larger skeletal elements, and plugged the open burrows with silt and sand.

Carbonate and clay translocation probably operated simultaneously in these soils and from their association in outcrop it appears that the reduced porosity of the illuviated clay horizons may have promoted the formation of more confined carbonate horizons immediately above. In this respect these soils are similar to calcic vertisols described by Blodgett (1985) and are indicative of multiple cycles of wetting and drying on a warm semi-arid floodplain. Carbonate precipitation around buried therapsid bones is again pervasive in these palaeosols and does not appear to be affected by the degree of pre-burial desiccation of the bone.

The morphologies and internal structures of the rough-surfaced calcareous nodules and sheets are comparable to the maturation sequence (I to V) for Quaternary calcretes described by Gile *et al.* (1966) and Hubert (1978). Over a period of some 10 000 years (Reeves, 1970; Williams and Polach, 1971) the BCa or 'K' horizon evolved from isolated glaebules and filaments (I) through a continuous increase in nodule density (II and III) until the horizon became completely plugged with carbonate (IV). Further modification by dissolution and re-precipitation formed laminar carbonate on the upper surface (V). By analogy, the fully developed floodplain palaeosols of the Lower Beaufort may indicate that extended periods of up to 10 000 years occurred between significant overbank floods that were capable of burying a soil profile. In effect this is a measure of the recurrence interval of the deposition of crevasse-splay lobes at any soil site.

Semeniuk and Searle (1985) describe three calcrete types from Holocene coastal sands (age 7 100 years BP) that closely match the morphotypes of the Lower Beaufort palaeocalcrete. They are:-

(1) vadose zone rhizocretions;

(2) non-pedogenic, thin-sheets (10 - 15 cm thick composed of mottled, massive and laminar types), in the zone of the capilliary rise above the water table'

(3) pedogenic brecciated calcrete.

Immature profiles are dominated by vadose rhizocretions whereas the mature landward profiles contain more mottled, massive and laminar calcretes of groundwater origin. The calcareous accretionary sheets of the proximal floodbasin palaeosols were possibly formed in a similar manner, just above the groundwater table, by capillary rise, and if so may be regarded as indicative of pedogenic maturity achieved within a 7 000 year time span.

Indirect evidence for the depth to watertable in these near channel palaeosols is indicated by the vertical dimensions of sand-filled therapsid burrow casts that project below, and are in lithological continuity with, the base of crevasse-splay sandstones (Smith, 1987b). Assuming that the terminal chambers were constructed above the water table, the minimum depth to water table for these palaeosols is +/- 1.5 m (Smith, 1987b).

The morphology and distribution of carbonate in the Teekloof palaeosols suggests that they formed under a semi-arid to arid climate with a mean annual moisture deficiency (McPherson and Germs, 1979). Comparable glaebule composition and textures occur in Pliocene to Holocene calcretes (Semeniuk and Searle, 1985; Netterberg, 1980; Watts, 1977), and especially with those of semi-arid alluvial plains (Sehgal and Stoops, 1972; Butler, 1958).From these studies it is inferred that the Teekloof climate was warm to hot (mean annual temperatures 16 - 20 degrees C or possibly as high as 25 degrees) and had a seasonally distributed rainfall of around 500 mm, but could have been as much as 800 mm per annum (Semeniuk and Searle, 1985).

3.2.3. Distal Floodbasin Palaeosols

The parent materials of these soils were deposited in the axial depressions of floodbasins far from the main rivers (Fig. 44). They consisted of thinly bedded dark grey and dark brown muddy silts with thin persistent beds of green silty sand and horizontally laminated fine-grained sand. Horizons of sand-filled polygonal desiccation cracks are fairly common in these deposits. The sand is probably of aeolian origin because in most occurrences, there is no lithological continuity with the overlying bed.

Calcareous nodules are not as common in this facies as in proximal floodbasin and channel bank deposits although a distinctive type of palaeocalcrete, consisting of a polygonal network of calcareous nodular material, is rarely encountered. Within the network, mottled mudrock is ramified by numerous millimetre-thick veinlets of calcite (Fig. 55). These polygons appear to have been formed by preferential cementation of more porous silty and sandy mudcrack-fills at, or just beneath, the floodplain surface. Layers of reddish-brown quartz pseudomorphs of gypsum in "desert rose" crystal habit are rarely found in this facies (Fig. 57). They are generally hosted by a highly disrupted reddish-brown muddy siltstone which weathers easily to release the distinctive "desert rose" clusters.

Thin beds of highly silicified siltstones ("cherts" of Rossouw and De Villiers, 1952) and horizons of small siliceous septarian nodules (Fig. 56) are found in some distal floodbasin sequences of the Teekloof Formation. The chert bands are more common and more widespread in the underlying Abrahamskraal Formation. These beds have distinctive horizontal, rippled and convoluted laminae and a pink weathered-surface colouration (Fig 43). More rarely, quartz pseudomorphs after gypsum occur as numerous individual "desert rose" and "rosette"-shaped clusters (Stear, 1980) lying along a single bedding plane (Fig. 57).

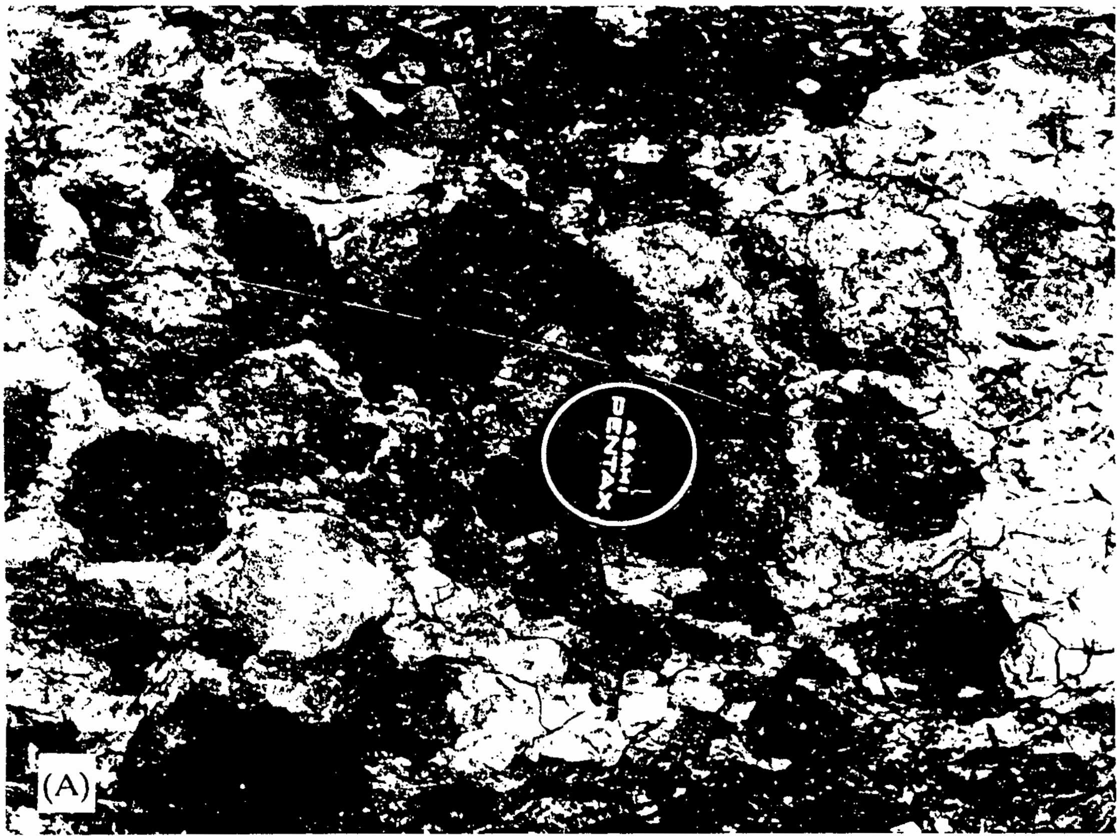
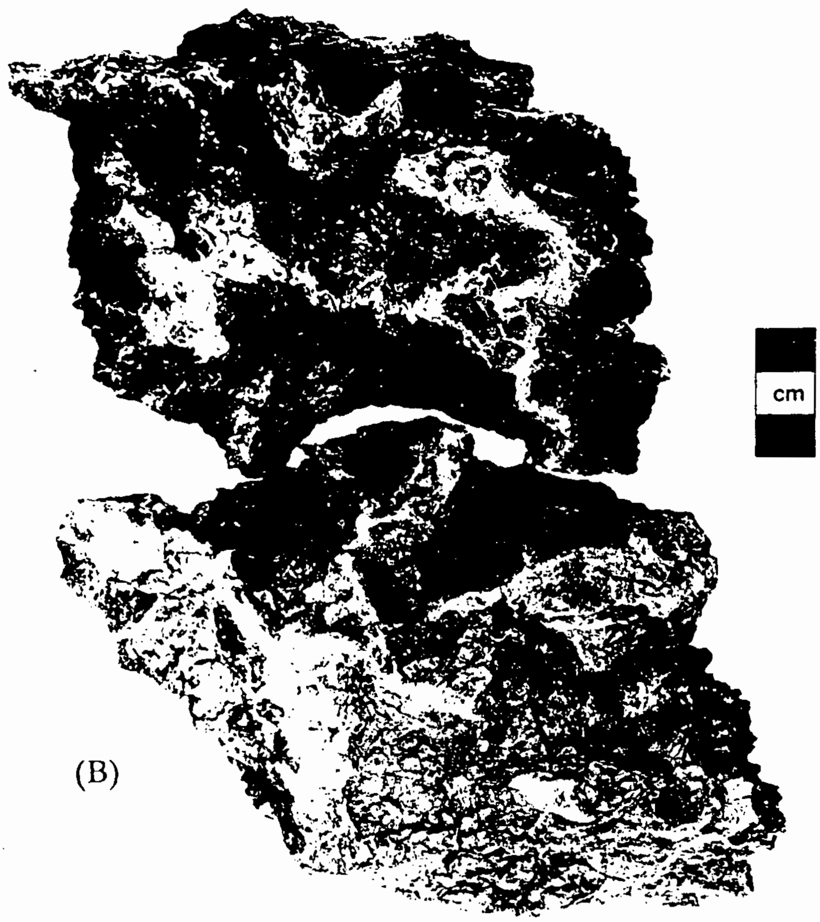


FIG. 55 (A) Polygonal Network of palaeocaliche in distal floodbasin mudrocks..
(B) closer view of caliche veinlets that ramify the host mudrocks between the polygonal network of calcareous nodular material.



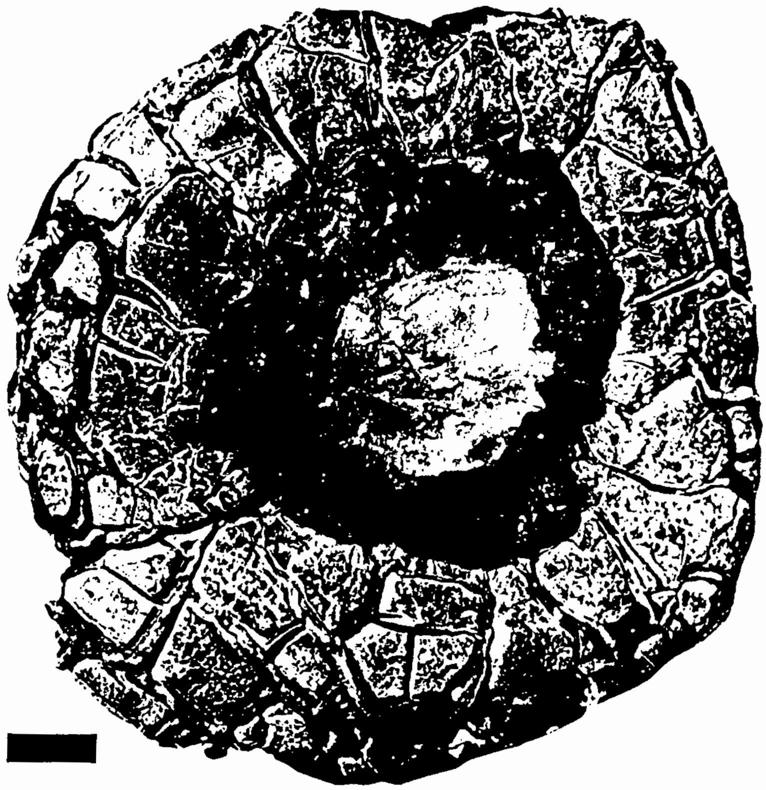


FIG. 56 A siliceous, platelet-shaped septarian nodule from distal floodbasin mudrocks. Scale bar = 1 cm.

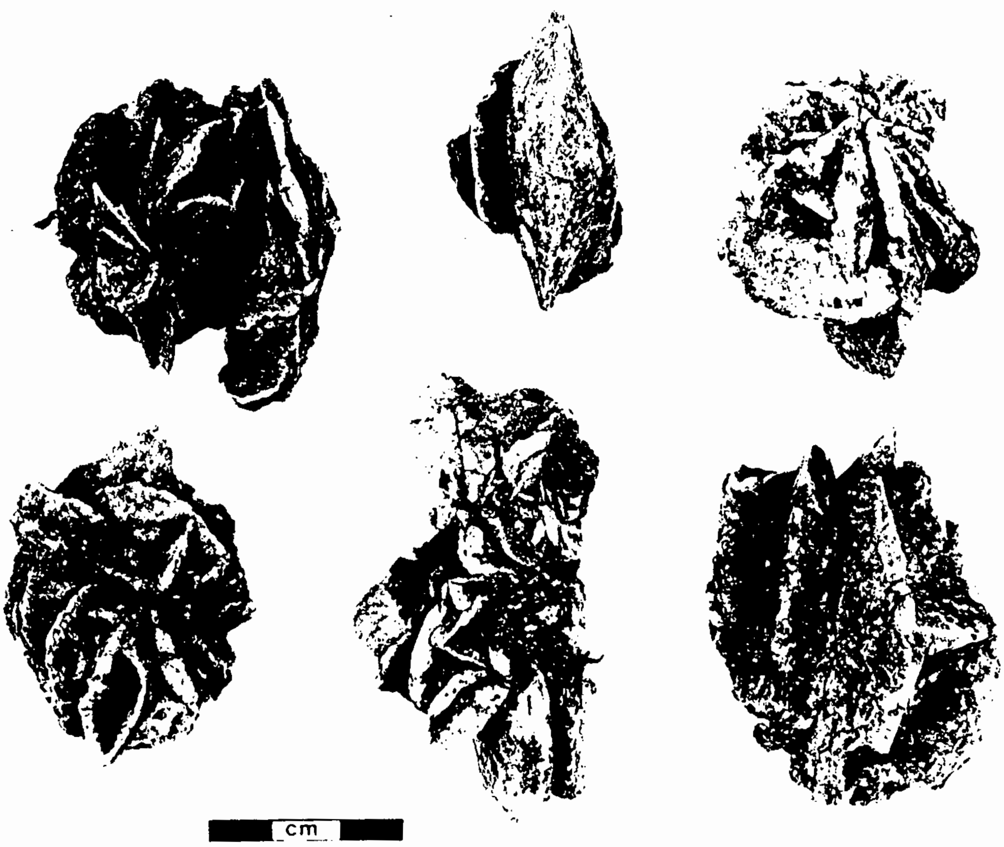


FIG. 57 Quartz pseudomorphs after gypsum "desert rose" crystal clusters from distal floodbasin deposits on Leeukloof (Locality L1 of Fig. 9).

The septarian nodules vary in shape from slightly flattened sphere, through biconvex "muffins" to biconvex "platelet" (Fig. 56). Microprobe and X-ray analyses (Smith, 1981) indicate a microcrystalline silica groundmass, with both fibrous and equant calcite mineralization in the cracks, and stringers of haematite and manganese oxide. These nodules were probably formed as replacements of calcareous nodules under hydromorphic conditions. The original lime mud was possibly precipitated at the sediment-water or sediment-air interface and went through a gel-like phase in the initial stages of growth, followed by case-hardening and colloidal contraction due to chemical desiccation (syneresis) (Brewer, 1964; Neal, 1978). Perhaps a more feasible explanation for septa formation in calcareous nodules was proposed by Astin (1986) involving compaction and overpressurization of the nodule following rapid burial. Mechanical cracking may occur after burial beneath as little as 50 cm of fine-grained sediment.

Vertebrate fossils are rare in the distal floodbasin deposits and comprise mainly small isolated post-cranial elements such as vertebrae and ribs (Taphonomic classes F, G and H of Appendix Figs. 8 and 9). Amphibian skeletons are usually more articulated, and display evidence of sun-cracking and flaking due to pre-burial weathering.

3.2.3.1. Interpretation

Pedogenic horizonation of the distal floodbasin deposits is minimal because the solum is not characterized by downward translocations but by high groundwater conditions and surficial evaporite precipitation. The pedogenic immaturity in this case is not the result of repeated burial, as with the levee palaeosols, but is due to an almost permanently saturated lower profile and the complete submersion of the entire solum for extended periods. Although with such low sediment accretion rates there was ample time for mature profiles to develop in the distal floodbasin, the low topographic position and high water table possibly "drowned" these soils leaving only the upper layers pedogenically active. It is in these upper layers that evaporative pumping led to the precipitation of carbonate and gypsum cements in more porous beds and between impermeable layers.

The common occurrence of polygonal networks of calcareous nodular material in these beds is perhaps indirect evidence for a continuous flux of calcium carbonate dust from the atmosphere, that settled on the floodplain. It could explain the abundance of carbonate in the soils which were developed from generally carbonate-poor parent alluvium (Yaalon, 1954; Mayer *et al.*, 1988).

Several workers have found volcanic glass shards in the Lower Beaufort cherts and this has led to the proposal of a tuffaceous origin (Martini, 1974; Ho Tun, 1979). The palaeoenvironment, mode of occurrence, and sedimentary structures of the "cherts" (Fig. 21) are strikingly similar to quartz-rich lime sandstones of the 'lacustrine yellow dolostone facies' described by Clemmensen (1978) from the Triassic of Greenland. It is proposed that the Lower Beaufort cherts were marginal lacustrine carbonates that accumulated in the seasonally exposed surface muds around playa-type lakes and onto which a rain of volcanic ash fell. Diagenetic solution of the glass shards would have released silica and could subsequently have replaced the surrounding carbonate to form a preferentially silicified chert layer.

Recent experimental work on the control of gypsum-crystal morphology in saline terrestrial environments (Cody and Cody, 1988) has shown that "desert rose" and "rosette" habits similar to those found in the distal floodbasin facies of the Teekloof Formation are formed in warm saline continental sediments containing concentrations of humic compounds. Such conditions are likely to have prevailed in the shallow-water evaporitic lakes of the distal floodbasin of the Lower Beaufort, which were fed by ephemeral streams draining the vegetated meanderbelt ridges.

4. VERTEBRATE TAPHONOMY

4.1. INTRODUCTION

In 1940 Efremov, who has been dubbed "the father of modern taphonomy", published a synthesis of the aims and scope of taphonomy which he defined as "the study of the transition (in all its details) of animal remains from the biosphere into the lithosphere".

This has since been modified to include organisms other than just animals and is now defined as "a broad field of integrated study of fossil beds from both biological and geological points of view in order to interpret their occurrence (Dodson, 1971).

Because the transition from living to fossilized states is so complicated, there are several ways in which it may be studied, each concerned with different stages in the passage from living community through death, decomposition, disarticulation, transportation, embedding, burial, fossilization, diagenesis and structural distortion before being exposed and finally recovered.

This study is primarily concerned with vertebrate fossils and their host sediments and is aimed at reconstructing, from all available clues, the post-mortem pre-burial history of these fossils. Efremov (1940) used the term "biostratinomy" to describe this particular avenue of research. Similar studies have been carried out on North American dinosaurs of the Cretaceous Oldman Formation (Dodson *et al.*, 1980) and Judith River Formations (Wood *et al.*, 1988) and the Jurassic Morrison Formation (Dodson *et al.*, 1980) as well as on fossil mammals of the Miocene Siwalik Group in Northern Pakistan (Behrensmeyer, 1988, 1987; Badgley and Behrensmeyer, 1980).

To date there has been very little taphonomic research done on the Lower Beaufort vertebrate fossils. Colbert (1963) was perhaps the first to use palaeontological evidence from the Lower Beaufort in palaeoclimatic reconstruction. Hotton (1967) recognized some fundamental taphonomic differences in the Lower Beaufort occurrences including the "head-only" assemblages described in this report. Boonstra (1969) noted that some parieasaurian fossils that were preserved fully-articulated in an upright attitude with their heads up were possibly mired in a floodplain pond. He also observed that the scarcity of articulated remains of dinocephalians was an indication that they lived in upland areas.

In a pioneer taphonomic study of the Lower Beaufort floodplain deposits, Smith (1980) interpreted the differences in articulation ratio and preservation of vertebrate fossils as a reflection of energy-levels in various sub-environments. The present study is a continuation of this research with more attention paid to other taphonomic parameters that have affected the preservation of fossils in the Teekloof Formation.

Most of the fossils that were found *in situ*, during the course of this study, have been taphonomically assessed (see Appendix Fig. 23). This involves field documentation of various aspects of the fossil such as field identification (usually to generic level), locality information and biozone, taphonomic class, attitude of skulls, type of peri-mineralization, skull length, presence of tusks, colour of bone, lithology of matrix and, on certain outcrops, the sedimentary facies of the host sequence.

Figure 59 plots the distribution of fossils found in areas where facies analyses have been conducted. It shows that the proximal floodbasin deposits are generally the most fossiliferous, followed by the channel bank (levee) and distal floodbasin deposits. Channel deposits, although often containing bone fragments in their basal lag conglomerates, are the least fossiliferous. This is in contrast to the occurrence of dinosaur fossils in the Dinosaur Provincial Park (Dodson *et al.*, 1980; Wood *et al.*, 1988) where the bottom channel deposits contain the most prolific bone concentrations and floodplain deposits are generally barren.

FIG. 59

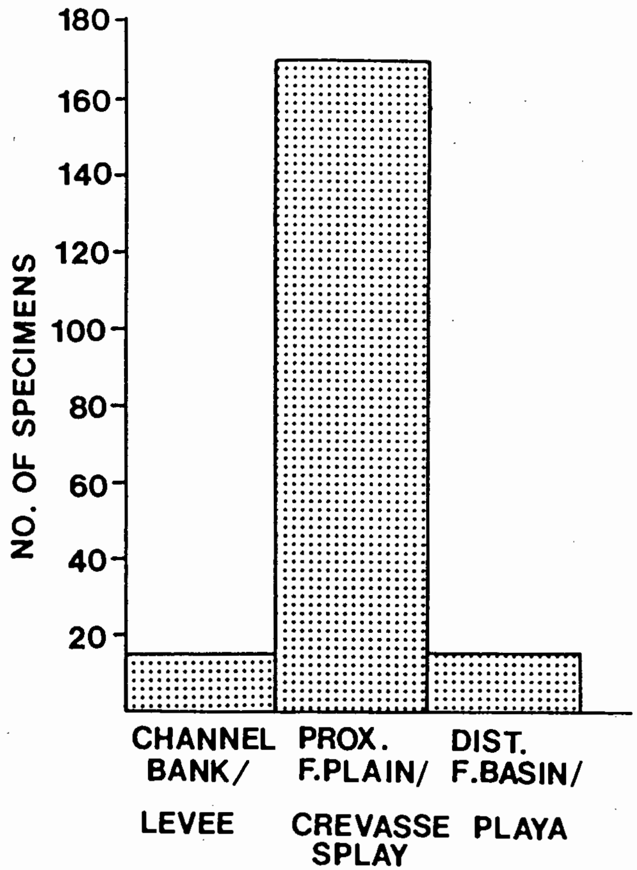


FIG. 58

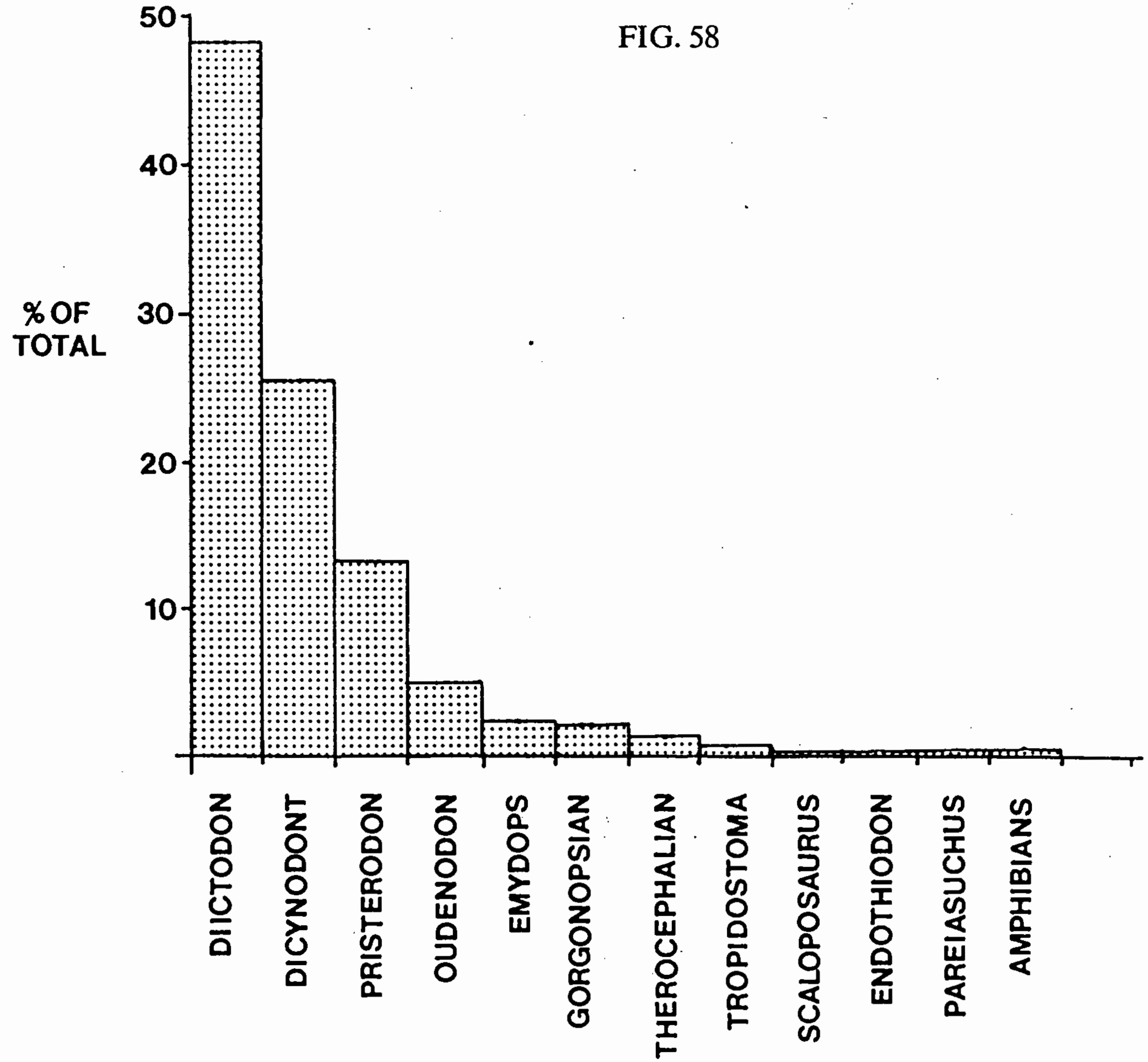


FIG. 58 Relative abundance of genera among the 940 fossils that were taphonomically assessed from the study block and are now stored in the Department of Karoo Palaeontology, South African Museum. Note how *Diictodon*, *Oudenodon* and indeterminate dicynodonts dominate the fossil fauna of the Teekloof Formation.

FIG. 59 The abundance of therapsid fossils in each of the three overbank facies associations that were recorded on 11 macrostratigraphic measured sections in the study block.

Figure 58 illustrates the frequency distribution of the various types of fossil found in the study area and highlights the relative abundance of *Diictodon* in these strata.

Paragraphs 4.1.1. to 4.1.5. include an analysis of the taphonomic assessments, the results of which are considered applicable to the Teekloof fauna as a whole. This is followed by more detailed description and interpretation of the main taphonomic of vertebrate fossil assemblages in each interchannel facies.

4.1.1. Taphonomic Class

Within the Teekloof depository, the disarticulated skeletal elements of mammal-like reptiles and amphibians were the largest sedimentary particles on the floodplains. Source areas for the major rivers were at least 1000 km away and sediment supply to this part of the alluvial plain was depleted in bedload that was coarser than medium-grained sand. However, it is evident from palaeohydraulic analyses (Smith, 1987) that the lack of coarser clastics in the floodplain deposits does not necessarily imply that the flow velocities were too low or that discharge was inadequate. It appears that there was a shortage in sediment supply in these size grades. Such a shortage may have been caused by easily disintegrating, homogeneous, fine-grained source rock. It is more likely, however, that most of the coarser sediment load was "stored" upstream in large tectonically-sustained, alluvial fan systems emanating from the points at which the main rivers emerged from the uplands.

The absence of predators with dentition capable of crushing bones means that carnivory could not have been a major factor causing the disarticulation and dispersion of larger skeletons on the floodplain. However, the bone shards that have been found in many of the carnivore coprolites show that some bones were ingested (see Fig. 54). This may have been accidental ingestion whilst scavanging a large prey but more likely these shards originated from smaller infant and juvenile prey that could be swallowed with minimal chewing.

		TAPHONOMIC CLASS	TRANSPORTATION	DURATION OF POST MORTEM/PREBURIAL PERIOD
PRESERVED AT SITE OF DEATH	A	Complete articulated skeleton in "curled up" attitutde - sometimes paired	No transportation (preserved in burrow)	V. Short
	B	Complete or near complete skeleton with straight or reflexed spinal curvature - sometimes paired	Slightly rolled (preserved in burrow)	Short
PRESERVED NEAR SITE OF DEATH	C	Skull with articulating cervical vertebrae and lower jaw	Lag - Short distance transport	Short
	D	Skull with displaced lower jaw		Long
	E	Skull without lower jaw		Long
	F	Lower jaw		Long
PRESERVED FAR FROM SITE OF DEATH	G	Accumulation of variety of small post-cranial elements into "bone bed"	Long distance transport reworked & winnowed & sorted	V. Long
	H	Isolated and/or fragmented ribs limb bones and vertebrae	Long distance transport	V. Long

TABLE 4 Taphonomic classes of *Diictodon* based on the degree of disarticulation of the skeleton.

Because the Teekloof predators were adapted to a flesh-tearing, scavenging feeding habit the degree of articulation of medium to large therapsid skeletons in the Teekloof Formation may be taken as a crude indicator of the length of time the skeleton lay undisturbed on the floodplain surface before final burial. From the author's collection of some 2 500 in situ fossils from the south-western Karoo it is possible to identify regularly recurring patterns of skeletal disarticulation, disassociation and dispersion that are formalized into 8 taphonomic classes (A - H of Table 4).

Although the progressive disarticulation trend from class A to H is broadly linked to increasing "residence time" on the floodplain surface, there is an important exception that was discovered during the course of this study. Taphonomic classes A and B are, in some cases, the result of the animal having died within the confines of underground burrows. Because these skeletons were not subjected to the same taphonomic processes as those that lay on the floodplain surface, their high degree of articulation need not necessarily reflect a short post mortem/pre-burial period.

Taphonomic classes C, D, E, F, G and H, therefore, reflect the fundamental decompositional classes of skeletons that were exposed on the ancient floodplain surface. The degree of completeness and articulation of these fossils reflects their resistance to a variety of dispersal processes that affected the skeleton after death and before final burial.

Some environmental factors operating to resist disarticulation and dispersal of mammal-like reptile skeletons may have been:-

1. Desiccation of ligaments and mummification of the leathery skin soon after death.
2. Protection from scavenger attack - death within an inaccessible or inhospitable area, eg. crevasse channel, erosion gulley.
3. Protection from trampling - death in inaccessible or depopulated areas such as the dry floodplain surfaces away from drainage channels.

4. Large dense bones such as the femur or skull of an adult *Endothiodon* - too heavy to be entrained by most sheet floods.
5. Rapid sediment accumulation - death at site of active sedimentation. Death and burial in the same event, eg. flash flood.
6. Anchorage of carcasses by vegetation or quagmire preventing entrainment and encouraging burial.

Factors promoting skeletal disarticulation and dispersal may have been:-

1. Mastication and ingestion of small animals by carnivores.
2. Scavenging and bone gnawing of larger carcasses by carnivores.
3. Excessive trampling eg. death at edge of water hole or on migration path.
4. Complete decomposition of flesh and ligaments by bacterial action in permanently saturated environments eg. spring hollows and perennial lake margins.
5. Small bones - easily entrained by low-velocity, shallow sheet floods.
6. Death in the confines of the main channel where multiple reworking of point-bar sediments is likely.
7. Death within areas of very slow sediment accretion rates that allow enough time for excessive bone weathering.
8. Absence of vegetation for anchoring carcasses and promoting localized sedimentation during floods.

Using the present method of taphonomic assessment, it is possible to determine whether a skeleton was disarticulated and dispersed by carnivory, trampling, in situ weathering or sheet floods. All these processes operate within relatively short term time frameworks. There is a longer term time constraint imposed by the overall rate of floodplain accretion that determines the maximum "residence time" of a skeleton on the surface of the floodplain before being buried. With increasing distance from the main channel the rate of floodplain accretion decreases and, correspondingly, the residence time of skeletons increases. If the "residence time" is longer than the time taken to reach late stage bone weathering, the bone has little chance of preservation.

Thus it is possible to use the taphonomic class structure of vertebrate fossils in a particular sequence of sediments to corroborate and quantify the general accretion rates interpreted from the sedimentary structures and palaeosols.

Figure 60 shows the taphonomic class distribution of all the in situ fossils assessed from the three study areas. It clearly shows that taphonomic classes D and E, being isolated skulls, are far more common than the more highly-articulated or the more dispersed groups. There may be some collector's bias against finding the more dispersed skeletons in that isolated skeletal elements are smaller and less easily spotted. However, the dominance of "skull only" occurrences over the more articulated skeletons is an obvious feature of the fossil fauna that needs explanation.

To facilitate direct comparison between the taphonomic characteristics of different facies and to prevent any natural variations in the living population structures from influencing the results, the taphonomic class distribution of a single genus, rather than the fauna as a whole, was analysed. The dicynodont genus, *Diictodon*, was the obvious candidate, being of medium-size, occurring in all floodplain facies, and by far the commonest genera found in all three study areas (Figs. 58 and 59).

Figure 61 shows the taphonomic class distribution of *Diictodon* in the three main floodplain facies. The proximal floodplain facies contains the largest range of taphonomic classes being similar to the channel bank facies in the distribution of classes C - H but having, in addition, a significant number of fully articulated skeletons (classes A and B). Some of these highly articulated skeletons have been shown to be preserved in underground burrows that were catastrophically-filled with crevasse-splay sands.

4.1.2. Attitude of Skulls

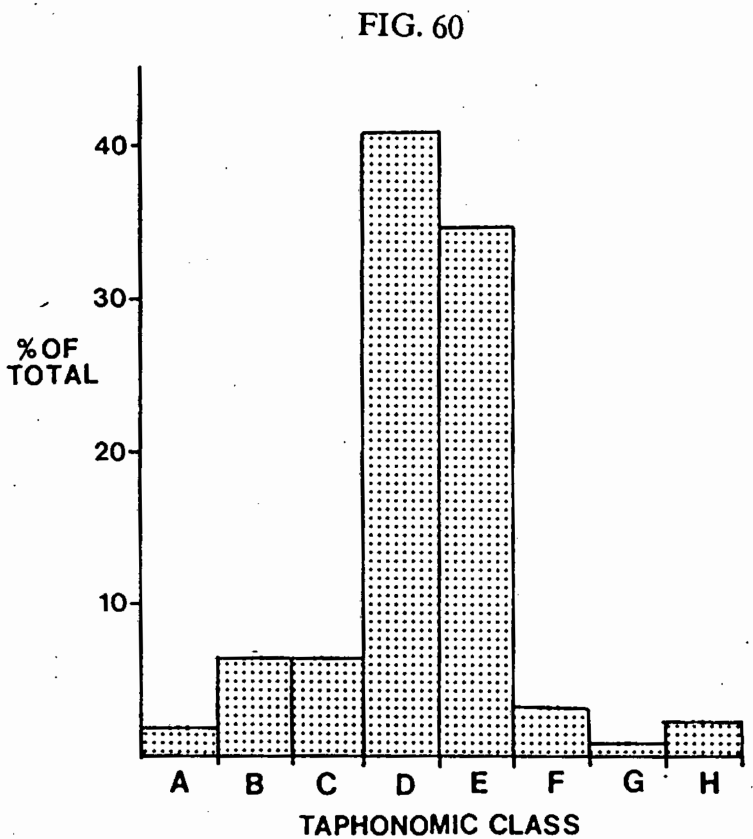
The attitude of isolated fossil skulls is their three dimensional position in the rock relative to surrounding bedding planes. This may be expected to vary according to:-

1. The size and shape of the skull influencing its hydrodynamic, aerodynamic and gravitational stability.
2. Embedding mechanisms such as localized scour around an obstruction to flow (Behrensmeyer, 1975) or trampling (Behrensmeyer, *et al.*, 1986).

By analysis of the attitudes of numerous isolated skulls from a particular facies, it should be possible to predict the major processes of embedding. In this analysis only the skulls of *Diictodon* are used. The attitude of each in situ skull was recorded, before being lifted, and described as either dorsal-up, ventral-up, lateral-up, dorso-lateral-up, anterio-lateral-up, etc.

The attitude of a skull (or any three dimensional fossil for that matter) in relation to the vertical compressional forces imparted by the accumulation of overburden is important in determining the pattern of stress and breakage points of the fossil. The pattern of breakages of *Diictodon* skulls lying in each of the commonly occurring attitudes is predictable. Thus, by simply studying the pattern of compressional damage, it is possible to establish the in situ attitude of a skull that has been lifted and prepared.

Figure 62.1 shows a plot of the attitudes of all the in situ isolated *Diictodon* skulls found in the study areas. Figures 62.2 and 62.3 show how the presence of an articulating lower jaw very strongly influences this attitude. Skulls that have a lower jaw are much more likely to be preserved lying on their side (lateral-up) whereas those without are most commonly buried dorsal-up although a considerable number were found ventral-up. This reflects the attitudes of maximum gravitational and hydrodynamic stability of these skulls.



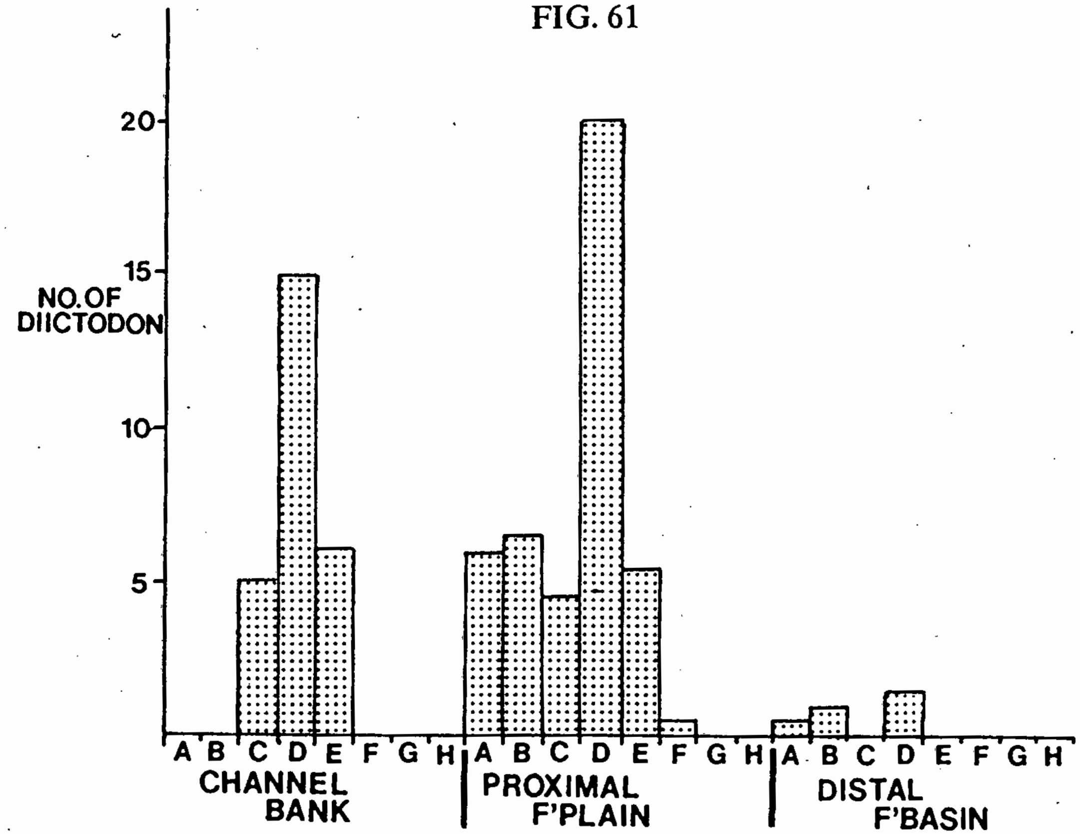


FIG. 60 Taphonomic class distribution of therapsid fossils recovered from the study block highlighting the anomalously high proportion of "skull-only" occurrences (Taphonomic calsses D and E),

FIG. 61 Taphonomic class distribution of *Diictodon* fossils in the three main interchannel facies of the Teekloof Formation showing that the proximal floodplain facies contains the more highly articulated specimens (classes A, B and C) which is, in part, attributed to the burrowing behaviour of small dicynodont.

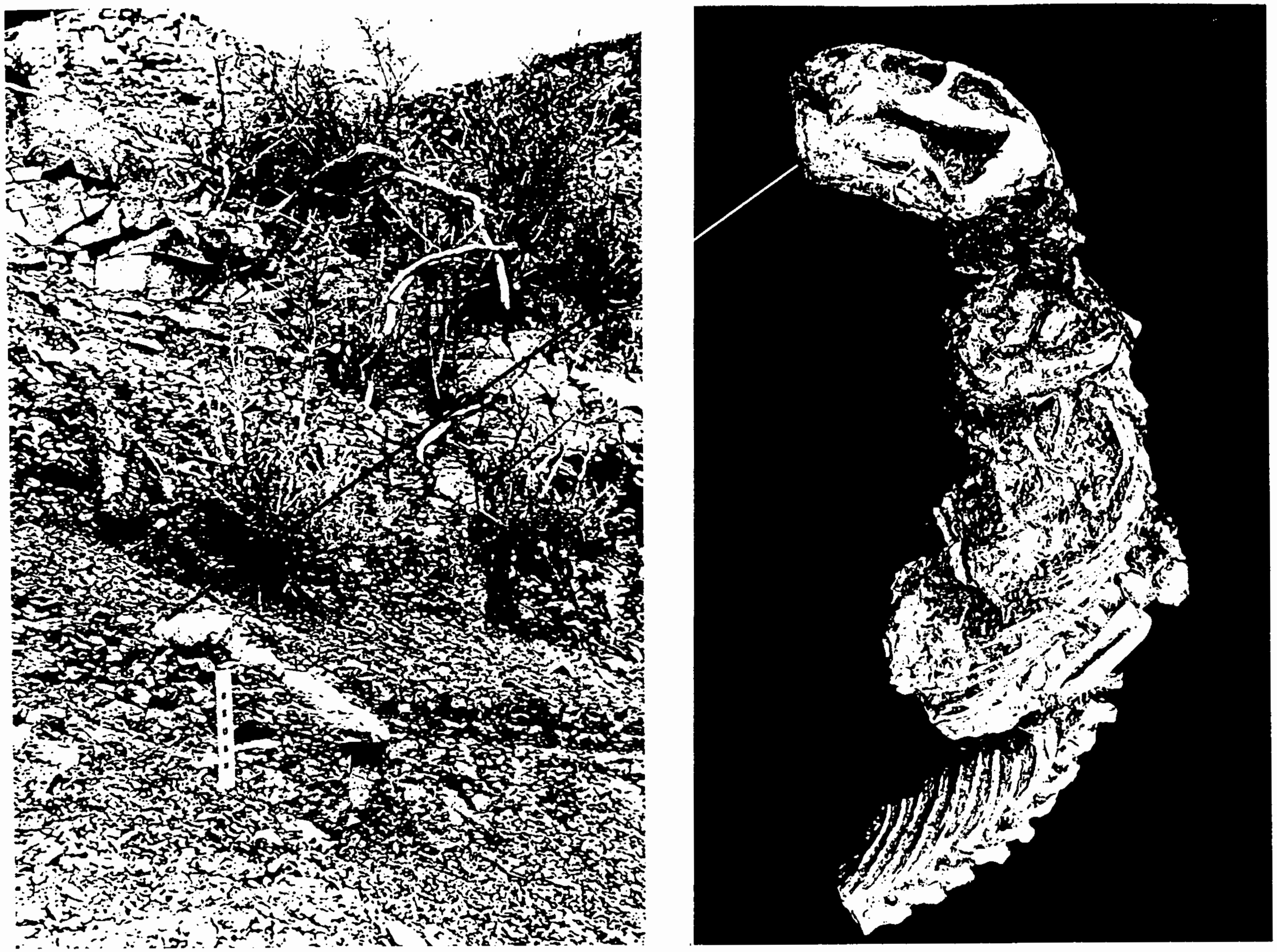


FIG. 63 Two "intertwined" articulated skeletons of adult *Diictodon* found lying across bedding planes at an angle identical to the ramp angle of a nearby sand-filled burrow cast (shown in Fig. 29). Although not clearly defined it is possible that they were entombed in the spiral of their burrow by a sudden collapse brought on by flash flooding. Note that one is lying head-up and the other, head-down. Scale in cm.

Anomalous skull attitudes are possibly caused by a "self-burial" mechanism described by Behrensmeyer (1975) whereby the skull topples into a scour pit excavated by turbulent eddies flowing round the stationary skull. Trampling is another effective embedding mechanism (Behrensmeyer, *et al.*, 1986) that can cause anomalous attitudes tangential to the bedding.

Burial within underground burrows (Smith, 1987b) also causes some anomalous skull attitudes although these normally involve more articulated specimens such as that shown in Figure 63 from the Teekloof Pass burrow locality.

4.1.3. Peri-mineralization

At least 90% of the fossilized bones in the Teekloof Formation are either completely or partly peri-mineralized by variable thicknesses of smooth surfaced micritic nodular material, laminar calcite layers, or, more rarely, pustular iron-rich calcareous nodular material.

Figure 64 is a photomicrograph of the sharp contact of smooth-surfaced nodular micrite around a therapsid long bone. There is a narrow zone of fibrous calcite crystals, orientated normal to the bone surface, separating the bone from the micritic cemented siltstone that forms the bulk of the peri-mineralizing layer. Although cracked, the original bone surface (the periosteum) is relatively intact.

Similar fibrous calcite layers, or rather laminae, form in the mudrocks surrounding many of the fossils whether they are peri-mineralized or not. They appear to have formed after compaction as they occupy gaps between the bedding planes that were opened up by differential compaction around the bone. Whilst collecting they are used as an indicator of fossil bone and were possibly formed after de-calcification of the bone and before silicification took place.

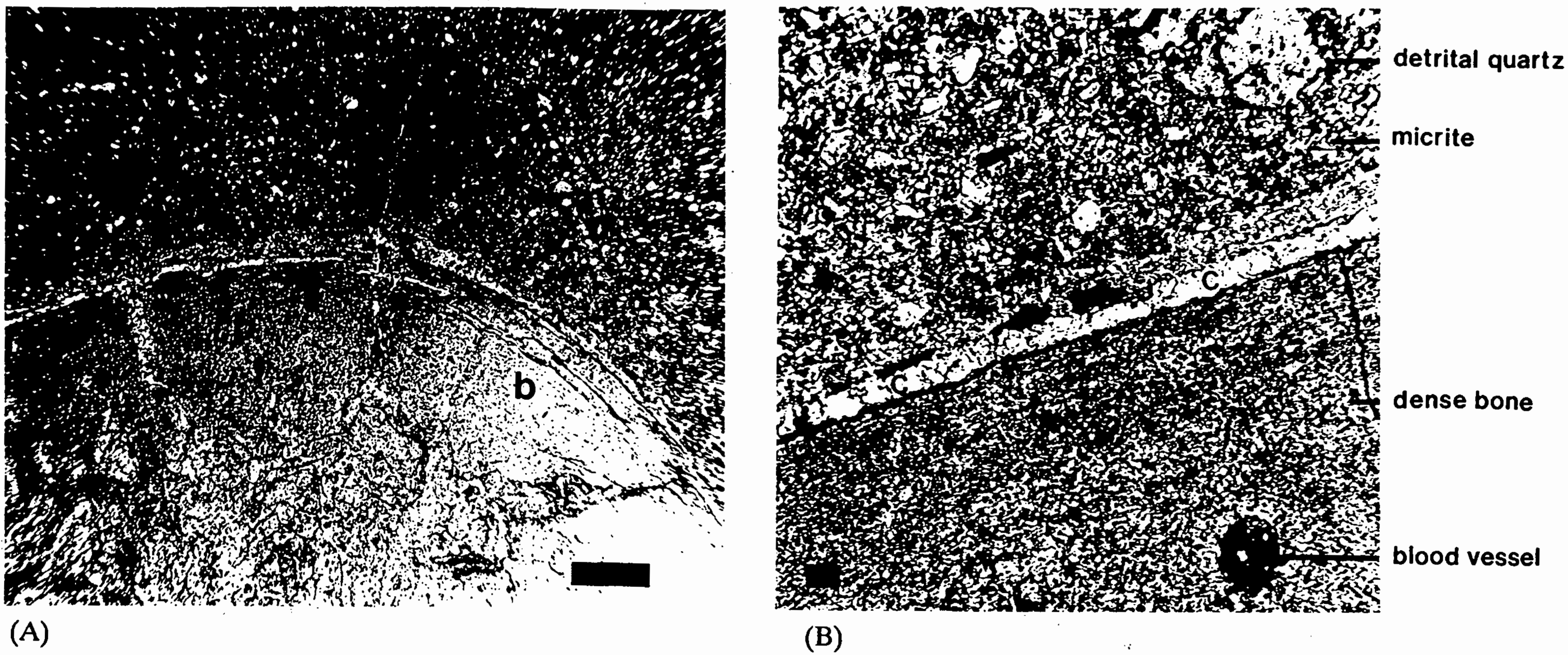


FIG. 64 (A) Photomicrograph of the contact between a fossilized therapsid bone (b) and its enclosing micritic nodule (n). Note the narrow laminar calcite layer (arrowed) between the bone surface and the matrix of the enclosing nodule. Scale bar = 5 mm.
(B) Closer view of laminar calcite layer (c) showing it to be made up of equant calcite crystals orientated normal to the bone surface. Note the detrital quartz in the micritic groundmass of the perimineralising nodular material. Scale bar = 1 mm.

Skulls that have been heavily peri-mineralized by micrite-cemented mudrocks are much less compressed than those with lesser or no peri-mineralization. This suggests that the peri-mineralization was consolidated earlier than its host sediments and probably before complete mineral replacement of the contained bone.

Slickensided surfaces are commonly observed in the host mudrocks immediately surrounding calcarous nodules and peri-mineralized bones. They too appear to have formed through differential compaction around a rigid consolidated nodule.

The mineralogy, structure and distribution of calcareous nodules in these strata indicate that they were precipitated by translocation of carbonates in the solum of palaeosols. It seems likely that the peri-mineralization of bones occurred at the same time, in the same place, as the development of palaeocalcrete horizons developed and may be attributed to an early diagenetic, pedogenic origin.

Several workers have suggested that there is an association between the burial of "fresh" unweathered bone and its early encrustation with calcuim carbonate (Konizeski, 1957; Bown, 1982). This is borne out by the bone-bearing coprolites found in the Teekloof Formation soils that originally contained "fresh" bone fragments when dropped and which must have been quickly and thoroughly calcified before deep burial so as to retain their perfectly cylindrical shapes (see Fig. 54).

4.1.4. Weathering Stage

All the vertebrate fossils recovered from the study areas have been allocated a number from 1 - 5 indicating the inferred degree of pre-fossilization weathering of the bones. These categories or "stages" are comparable to modern bone-weathering observations made by Behrensmeyer (1978). Personal observations of Behrensmeyer's taphonomic collection from the Amboseli National Park, Kenya, which is housed in the Smithsonian Institution in Washington, allowed for more detailed comparison.

Although there are differences in bone histology and structure between the Kenyan plains mammals and Karoo therapsids, the bones are similar enough in overall structure and composition for there to be many similarities in their weathering stages.

The following weathering stages of Karoo therapsids are described in terms of macroscopic features that are distinguishable on unprepared material in the field.

STAGE I

Long bones -

"Fresh-looking" bone surface that has no longitudinal cracks or fissures. Articular surfaces are still moderately well-rounded.

Skulls -

"Fresh-looking" bone surface. Sutures between individual elements of skull roof are tightly closed and almost invisible. Sclerotic plates sometimes preserved in place within the orbit.

STAGE II

Long bones -

"Fresh-looking" bone surface with some cracking and loss of surficial periosteal laminae and a few longitudinal cracks parallel to the shaft which taper towards the ends. Articular surfaces often have patches of cancellous bone exposed.

Skulls -

"Fresh-looking" bone surface with some cracking of the squamosals and post-orbital bars and areas, especially around the snout, where periosteal bone has flaked off. Sutures of the skull roof are open, especially the sagittally orientated one between the frontal bones. Tusks and teeth intact and uncracked.

STAGE III

Long bones -

"Fresh-looking" bone surface with longitudinal cracks, some which have opened into fissures, and flaking of periosteum along edges of cracks. Articular surfaces becoming flatter and mostly cancellous bone exposed.

Skulls -

"Fresh-looking" bone surface with longitudinal cracks in the squamosals, post-orbitals and pareital bones, flaking of rugose textured bone surface on nasals and pre-maxillae. Gaping of nasal and fontal sutures. Tusks intact and uncracked.

STAGE IV

Long bones -

Covered in longitudinal and radial cracks with almost complete loss of periosteal bone and a crazed weathering pattern of flaking sub-periosteum. Cancellous bone may be visible in places along the shaft. The convexity of articular surfaces is completely lost.

Skulls -

Most bones are cracked and fissured, post-orbitals and tusks are often missing. The caniniform processes and edges of squamosals are rough and splintered. All bones covered with microcracks giving a mosaic pattern that is most intricate in the inter-orbital and inter-temporal areas.

STAGE V

Long bones -

The dense periosteal bone has completely flaked-off. Inner cancellous bone is considerably cracked and fissured and the original bone shape is barely recognizable.

Skulls -

The bone/matrix contact is difficult to define due to severe flaking and splintering of the bone surface. Extensive marginal erosion of the squamosal and pre-maxilla bones. Post-orbital bars become detatched.

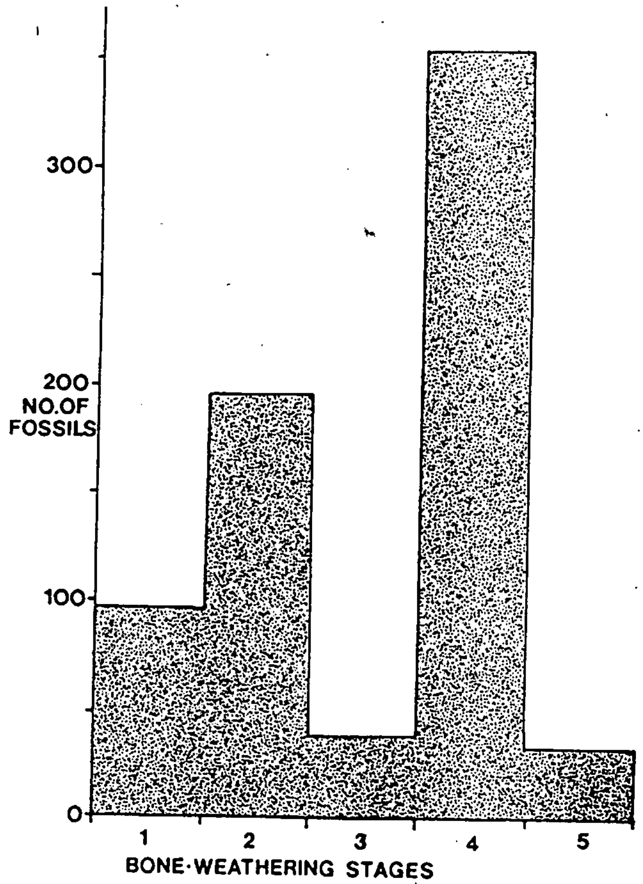


FIG. 65.1 Bone-weathering stages of all fossils recovered from the study block.

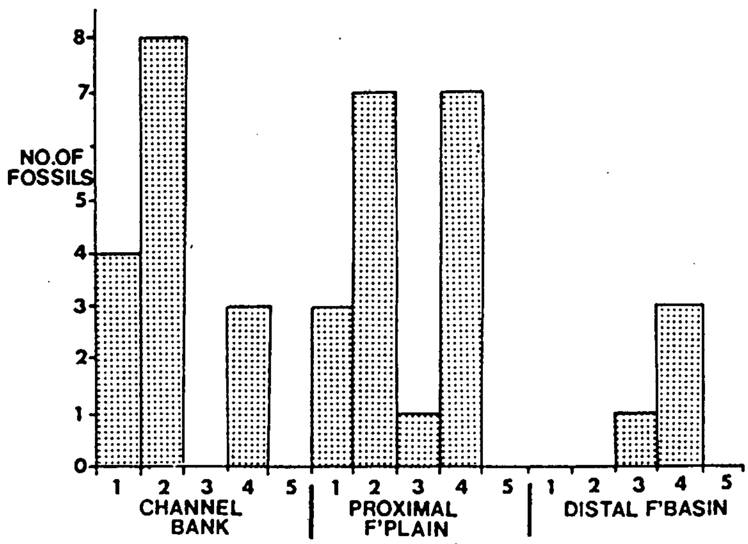


FIG. 65.2 Bone-weathering stages of *Diictodon* skulls recovered from the three overbank facies of outcrops that were studied in detail. B = channel bank facies, P = proximal floodplain facies, D = distal floodbasin facies.

Figure 65.1 shows a plot of weathering stage distribution amongst all the fossils collected, showing an overall "freshness" to the fossilized bone material. This observation has been made by many palaeontologists over the years and is a "hallmark" of the Teekloof fossil fauna.

Figure 65.2 is a breakdown of the distribution of weathering stages in the facies documented outcrops. Here it can be seen that the more weathered fossils are relatively more common in the distal floodbasin areas and the "fresher" bones are generally associated with the channel-bank and proximal floodplain facies. It can be seen, however, that the proximal floodbasin deposits have the largest range of weathering stages.

The pattern of weathering of therapsid bones in the Teekloof Formation reflects various amounts of exposure to desiccating agents which, as with the Amboseli mammals, is attributed to direct sunshine and wind. Behrensmeyer (1978) has shown that under semi-arid climatic conditions on a flat alluvial plain, medium-sized mammal bones take at least 6 years to reach stage V weathering. The most significant change in bone weathering textures occurs around 3 years after death when the bone changes from "fresh looking" (stages 0 - 1 of Behrensmeyer, 1978) to "slightly weathered" (stages 2 - 3).

This figure may confidently be applied to equivalent-sized Teekloof fossils because the interpreted environmental conditions are similar. Thus, another time constraint may be added to the facies analysis, that of minimum "residence-time" of bone on the floodplain surface to attain the minimum weathering stage. If this "residence time" is a function of floodplain sedimentation then it should be possible to quantify the minimum sedimentation rates for the various floodplain facies.

4.1.5. Bone Colour

Bone colours vary considerably within the Lower Beaufort fossil assemblages. In the lower strata of the Dinocephalian Assemblage Zone along the southern margin of the Karoo Basin the bone is generally darker in colour than higher up in the succession. These lower strata of the Abrahamskraal Formation contain a much higher proportion of dark blueish-grey, black and purple bone colours than higher up in the Teekloof Formation. In the study area the bone colours range from black to grey, light reddish-brown, cream and "porcelainite" white. There is no consistent relationship between the colour of fossil bone and the colour of the host matrix nor are any colours specific to any taxonomic group.

The colour of fossil bone appears to be related to late diagenetic and metamorphic alteration in that areas of high regional metamorphism, such as the Dinocephalian Assemblage Zone along the southern margin of the basin, have generally darker hues and a higher proportion of black bone.

In contrast, the degree of contact metamorphism of sediments in juxtaposition to dolerite sills and dykes may be visually assessed by the "whiteness" of fossil bone. Nearing the dyke margin the bone becomes gradually whiter and more brittle until a "porcelain-like" state is reached. Closer to the dyke the bone begins to disintegrate and within a few metres of the dyke margin empty moulds from which the bone has been completely "baked out" are commonly found.

4.2. VERTEBRATE TAPHONOMY OF CHANNEL-BANK DEPOSITS

Fossils in the channel-bank deposits are generally rare, consisting of skulls and isolated post-cranial elements such as ribs and limb bones, with a density in the order of 1 every 100 square metres of outcrop. There are, however, important exceptions to this general paucity of bone, where in patches of a few hundred square metres, bone becomes very common in the order of one specimen every 10 square metres. These relatively fossil-rich patches are invariably found in 2 - 3 metre thick inner-bank levee deposits directly overlying a high sinuosity channel sandstone. It is not easy to accurately define their areal limits but the host rocks form an elongate body some 50 - 75 m wide and up to 3 km long.

These rocks usually comprise massively-bedded greenish-grey fine-grained sandstone or siltstone up to 3 metres thick. All the fossils are completely peri-mineralized with smooth-surfaced calcareous nodular material (Fig. 46), some to such a thickness that the original bone shape is no longer discernable.

One such fossil-rich occurrence at the base of Eklipsberg in study area 2, lies on top of a major channel sandstone and has yielded hundreds of skeletons and skulls of *Diictodon*. Amongst the 52 fossils collected from this locality during this study there are 43 *Diictodon*, 2 *Tropidostoma*, 4 *Pristerodon* and 3 gorgonopsians (see Appendix Map 20; G.R. 32 degrees 08'45"S, 22 degrees 04'50"E). The *Diictodon* fossils were mostly isolated skulls both with and without lower jaws (classes D and E respectively), a few had articulated cervical vertebrae (class C) and one fully articulated class B skeleton.

The bone surfaces are relatively unweathered (stages 2 and 3) and light grey or cream coloured. The isolated *Diictodon* skulls lay in the predictable attitudes of lateral-up for those with lower jaws and dorsal-up, for those without.

Another outcrop of fossil-rich inner bank levee deposits occurs in Teekloof Pass (Appendix Map 19; G.R. 32 degrees 11'25"S, 21 degrees 37'30"E and Appendix Fig. 16) where 16 *Diictodon* fossils were collected from a 100 m long cliff exposure. The host sequence comprised a greenish-grey massive siltstone with large brown-weathering nodules directly and sharply overlying the topstratum deposits of an 8 m thick high-sinuosity channel sandstone.

The fossils comprise 12 skulls with lower jaws, 3 with articulating cervical vertebrae and 1 without lower jaw. All but one are of adults with skull lengths >50 mm, the exception, in the 25 - 50 mm range being classed as a juvenile. Of the 15 adult skulls, 11 are tusked suggesting that they are males.

A higher than average frequency of black-coloured bone occurs in 6 of the 16 skulls. Black bone is not specific to a particular matrix colour, matrix lithology, bone weathering stage or vertebrate taxon. It is possibly caused by metamorphism. These sediments have undoubtedly been "baked" by nearby dolerite intrusions but it is not known exactly how this affects bone mineralogy.

The geometry and position of these fossil-rich levee deposits in relation to the underlying point-bar suggests that they may be swale fills or possibly the fine-grained infilling of a chute channel. Similar floodplain channels are interpreted as the main depository for localized mammal bone accumulations in the Siwalik Group of Northern Pakistan (Behrensmeyer, 1987) and the much-quarried reptile bone-beds in the Permian "red beds" (Wichita and Clear Fork Groups) of Texas (Behrensmeyer, 1988; Sander, 1989). However, the bone density in the Lower Beaufort strata never approaches that of the bone-bed occurrences mentioned above although the degree of articulation is generally higher. The increased number of fossilized remains of therapsids in these rocks may have resulted from a combination of biological and hydrodynamic factors rather than a simple hydraulic "placer" model.

Swales, chutes and crevasse channels would have provided watering holes for much of the year. Carnivores, in taking advantage of the increased density of prey species, would have contributed more than the "background" number of small and medium-sized herbivore skeletons to the death assemblage in these areas (Behrensmeyer, 1987; Badgley, 1986; Conybeare and Haynes, 1984). It is possible that the high incidence of skull-only *Diictodon* fossils in these deposits is partially due to the opening-up of the neck region by carnivore attack thus accelerating the decomposition of ligaments and early disarticulation of the cervical vertebrae. In such a setting, trampling may have been an important taphonomic agent in disarticulating, breaking and embedding bones that lay around the waterhole (Behrensmeyer *et al.*, 1986).

Being close to the main channel, overbank flows had the competence to lift and transport the smaller non-embedded disarticulated skeletal elements, including infant and juvenile skulls as well as mummified carcasses (Hill, 1979) but not the larger elements such as skulls and lower jaws. Thus, although the initial abundance of *Diictodon* cadavers may have been due to biological factors, the composition of the fossil assemblage in these deposits was mainly determined by the hydrodynamic stability of individual skeletal elements and the buoyancy of mummified carcasses.

The skull is the largest single element of the *Diictodon* skeleton especially if the lower jaw remains in articulation as it appears to have done in a great many cases. This meant that of all the disarticulated elements the skull was the least likely to become entrained and transported (Voorhies, 1969). In fact, its hydrodynamic stability may have promoted embedding by creating turbulent eddies in the lee of the skull which excavated a scour pit into which the skull may eventually have toppled (Behrensmeyer, 1984).

Hill (1979) noted that desiccation of the skin covering the carcasses of small savanna mammals causes it to become mummified and hold the disarticulated bones in association indefinitely.It has been speculated that the therapsids had a leathery skin, some with embedded bony scutes, but no hair (Romer, 1966). Under the generally arid conditions of the Lower Beaufort floodplains their carcasses would have rapidly dried out, and mummification could well have played an important role in generating articulated fossils of taphonomic class B. The skin was closely attached to the skull of *Diictodon* and its cheeks or "mundplatt" (Crompton and Hotton, 1967) may have been inserted onto the lower jaw. Desiccation would have caused skrinkage of the fibrous mundplatt tissue effectively clamping the lower jaw closed and keeping it closed long after the adductor muscles had decomposed. The author has observed that tortoise skulls found in the Karoo today have their jaws held tightly closed by desiccated ligaments on the jaw articulation which cause the upper and lower parts of the curved horny beak to stay wedged together. Ligament desiccation and beak-wedging could have operated with *Diictodon* and may account for the relatively high ratio of fossil skulls with attached lower jaws compared to those without (see Figs. 60 and 61).

4.3. VERTEBRATE TAPHONOMY OF PROXIMAL FLOODPLAIN DEPOSITS

The proximal floodplain sequences of the Teekloof Formation are generally the most fossiliferous having a "background" bone density of 1 specimen every 80 square metres with patches where densities increase to 1 every 10 square metres. Appendix figures 8 and 9 show that the therapsid fossils cover a wider range of taphonomic classes and weathering stages than those of the channel bank and it is apparent that bone accumulating mechanisms on this part of the floodplain were slightly different.

The Wilgerboskloof outcrop (Appendix Fig. 9) has two sequences of proximal floodplain deposits from which 58 bone occurrences were logged. These sequences were separated by distal floodbasin deposits with 4 bone occurrences and channel bank deposits with 9 bone occurrences.

The Leeukloof outcrop (Appendix Fig. 8) has 3 sequences of proximal floodplain deposits from which 24 bone occurrences were assessed, 2 channel bank sequences with 3 bone occurrences and 2 distal floodbasin sequences that had no bone at all. Columnar sections of fossiliferous outcrops on Reiersvlei and Willodene (Appendix Figs. 13 and 15) show similar distribution.

The wide range of taphonomic classes in the proximal floodbasin deposits of these localities is demonstrated below.

	TAPHONOMIC CLASSES								TOTAL
	A	B	C	D	E	F	G	H	
Wilgerboskloof	3	14	6	20	6	3	1	4	57
Leeukloof	8	4	2	6	1	1	1	1	24
Willodene	1	1	7	7	6	0	0	0	22
Reiersvlei	0	7	2	5	5	0	0	0	19

TABLE 5: Taphonomic classes of all fossils found in four documented outcrops of proximal floodbasin deposits.

These data demonstrate the high proportion of articulated *Diictodon* skeletons along with a relatively high percentage of isolated skulls with lower jaws in these proximal floodplain deposits. The main distinction between the taphonomic signature of the channel bank and proximal floodplain deposits is that there are considerably more fully-articulated skeletons in the latter.

Preservation of *Diictodon* skeletons in underground burrows, casts of which which have been found at all 4 localities, certainly accounts for some of these highly articulated specimens (Smith, 1987b). The burrows were excavated into proximal floodplain soils, apparently as a mechanism to keep cool nearer the water table, and were often occupied by more than one individual. Catastrophic crevasse-splay progradation infilled many of the burrows with fine-grained sand and silt and in very rare instances buried an aestivating *Diictodon*. Mummified carcasses and disturbed but associated skeletons that were contained in the burrows at the time of flooding are found in the terminal chambers of some burrow casts (see Figs. 72).

The maturity of palaeosols in the proximal floodbasin deposits suggests that pedogenic processes must have affected the early diagenesis of these fossils to a greater degree than in the channel bank. The occurrence of mature palaeosols associated with higher than background bone densities suggests that these bones are mainly autochthonous attritional accumulations (Bown and Kraus, 1981b) on non-deposition surfaces rather than "catastrophic" biological or hydraulic concentrations. Thus the increased bone density in these palaeosols basically reflects an extended period of time,possibly as much as 10 000 years (Gile *et al.*, 1966),during which that area of the floodplain was not affected by major floods.

The low periodicity of major floodplain inundation allowed time for the skeletons that were exposed on the proximal floodplain to completely disarticulate and reach late stage weathering. During this period the floodplain accretion rates were minimal, in the order of 1 - 2 mm/year, possibly a result of regional drought but more likely due to avulsion of the main channel away from that part of the floodplain (Leeder, 1975; Allen, 1978). The next major sheet flood, probably heralded the arrival of an avulsed channel back into the area, was of sufficient competence to scour the floodplain surface and to transport the smaller post-cranial elements away from the site leaving skulls and lower jaws to be rapidly buried by traction load fines.

4.4. VERTEBRATE TAPHONOMY OF DISTAL FLOODBASIN DEPOSITS

Vertebrate fossils in the distal floodbasin sequences are scarce, being in the order of 1 specimen every 300 square metres and relatively poorly preserved. They consist of scattered post-cranial elements such as vertebrae, ribs and long bones (taphonomic class G). Skulls are rare and generally extremely compressed, strongly weathered and poorly peri-mineralized. Amphibian remains occur in these rocks as disarticulated but associated skeletons where the individual elements are not in articular contact but lie scattered in close proximity to each other.

Plant fossils, on the other hand, are relatively more common than in other interchannel facies. They occur in thin, dark reddish brown or black mudstone layers that persist along strike for several 10's of metres (see Dunedin cliff section Appendix figure 7). The upper surface of this bed is plastered with impressions of small *Glossopteris* leaves (maximum length 10 cm), equisetalean stem fragments (*Schizoneura*) and leaf whorls (*Phyllotheca*). Another site for the preservation of leaves is the mudstone veneered upper surface of thin (+/- 15 cm) distal crevasse-splay sandstones. The glossopterid leaves, which are mostly complete, are much smaller than those of the Ecca Group and appear to have grown in a more arid environment that caused xeromorphic reduction in leaf area. Their preservation on these sandstone surfaces is interpreted as resulting from strandline accumulations of seasonal leaf-falls on the downwind shore of a floodbasin lake.

Vertebrate footprints are also preserved on these distal crevasse- splay sandstone surfaces at several localities in and around the study areas (see Map 1). Their preservation is largely a function of a particular sequence of sedimentation whereby imprinted wet sand deposited around the mouths of distributary channels was quietly inundated by standing water as the lake level rose following a major overbank flood. At the Leeu River *Diictodon* trackway site on Waterval (Figs. 41 and 42) the potential for footprint preservation may have been increased by a layer of algae that protected and preserved the footprints as underprints.

Another trackway site near Fraserburg (De Beer, 1987; see Map 1 for locality) is on a distal crevasse-splay that shows obvious evidence of sub-aerial exposure and desiccation. In this case the preservation is due to the lake-level rising over the marginal sand flats soon after they were made, before the sand had completely dried out. Sometime later, however, after a thin layer of mud had been deposited over the surface, the lake-level dropped allowing the mud draped sand to dry-out and, in doing so, shrink to form polygonal desiccation cracks.

The taphonomic signature of the distal floodbasin deposits (Appendix Figs. 8 and 9) is indicative of very slow rates of sediment accretion on the shore and floor of floodbasin lakes. Although the sedimentation is essentially episodic, similar to the channel-bank and proximal floodplain, the paucity of bone suggests that firstly there were no biological bone-concentrating mechanisms operating (eg. waterholes, middens etc.) and secondly the long periods of exposure of bones on surface caused them to become severely weathered and to disintegrate especially on the upper surfaces. This disintegration may have been accelerated by the displacive growth of gypsum or salt beneath the cracked and fissured bone surface (Behrensmeyer, 1978).

4.5. THE TAPHONOMIC SIGNIFICANCE OF BURROWING THERAPSIDS

Large vertebrate burrow casts are very distinctive, although generally rare, trace fossils. They have been described from a number of fluvial successions dating back to the early Eocene (58 m.a.) although most are younger than early Miocene (22 m.a.) (Martin and Bennet, 1977; Bown, 1982; Bown and Kraus, 1983; Voorhies, 1975). All of the larger helical burrows (tube diameters greater than 40 mm) that have been described to date are fairly confidently attributed to the activity of rodent mammals.

During the course of this study at least 50 helical burrow casts and several straight burrow casts were discovered in all three study areas in the overbank mudrocks (Smith, 1987b; see Appendix Maps 19, 20 and 21). The helical burrow casts are grouped within the ichnogenus *Diamonelix* (Barbour, 1982) based on comparable preservation, architecture, surface textures and sedimentary environments but with nothing more than an ethological similarity between the diggers (see Table 6). The Lower Beaufort helical "diamonelices" and the straight to slightly curved decline burrows are both attributed to the digging activity of small dicynodonts.

Complete burrow casts are rarely found because their vertical attitude and intricate windings are, in most cases, entirely supported by rapidly weathering mudrocks causing exhumed parts of the burrow cast to fracture and fall away.

Observations of about 50 in situ helical burrow casts shows them to be composed of three sections: an upper decline, a middle spiral and a lower terminal chamber (Fig. 66). Tube diameters range from approximately 60 mm in the upper decline, progressively increasing through two dextral coils to approximately 160 mm at the base of the spiral where the tube straightens and widens to about 250 mm in a horizontal or slightly inclined elongate terminal chamber. Cross-sectional shapes of a typical calcretized helical burrow cast from the Teekloof Formation are shown in figure 66. All the burrow casts located to date are dextrally coiled. The

	Daimonelix	Beaufort helical burrows
Similarities		
Geological setting	Alluvial floodplain	Proximal floodbasin
Architecture	Upper entrance pit Middle vertical spiral Lower living chamber	Upper straight decline Middle vertical spiral Lower terminal chamber
Looseness of coiling	Mostly loose — some tight	Mostly loose — some tight
Whorl radius	Constant (10–15 cm)	Constant (10–15 cm)
Ramp angle of spiral	20°–40°	10°–30°
Differences		
Age	Lower Miocene 22 Ma	Upper Permian 240 Ma
No. of whorls	2–20	2(3)
Sense of coiling	Sinistral and dextral	Dextral
Tube diameters	Constant through spiral	Increasing through spiral
Attitude of terminal chamber	Mostly inclined up to 30°	Mostly horizontal some slightly inclined
Enclosed fossils	Articulated and disarticulated remains in living chamber. Mostly *Palaeocastor*, a primitive beaver.	Articulated remains in terminal chamber and lower whorl. All *Diictodon*, a herbivorous mammal-like reptile.

TABLE 6 Comparison of *Diamonelix* with helical burrow casts of the Lower Beaufort. *Diamonelix* data from Martin and Bennet (1977)

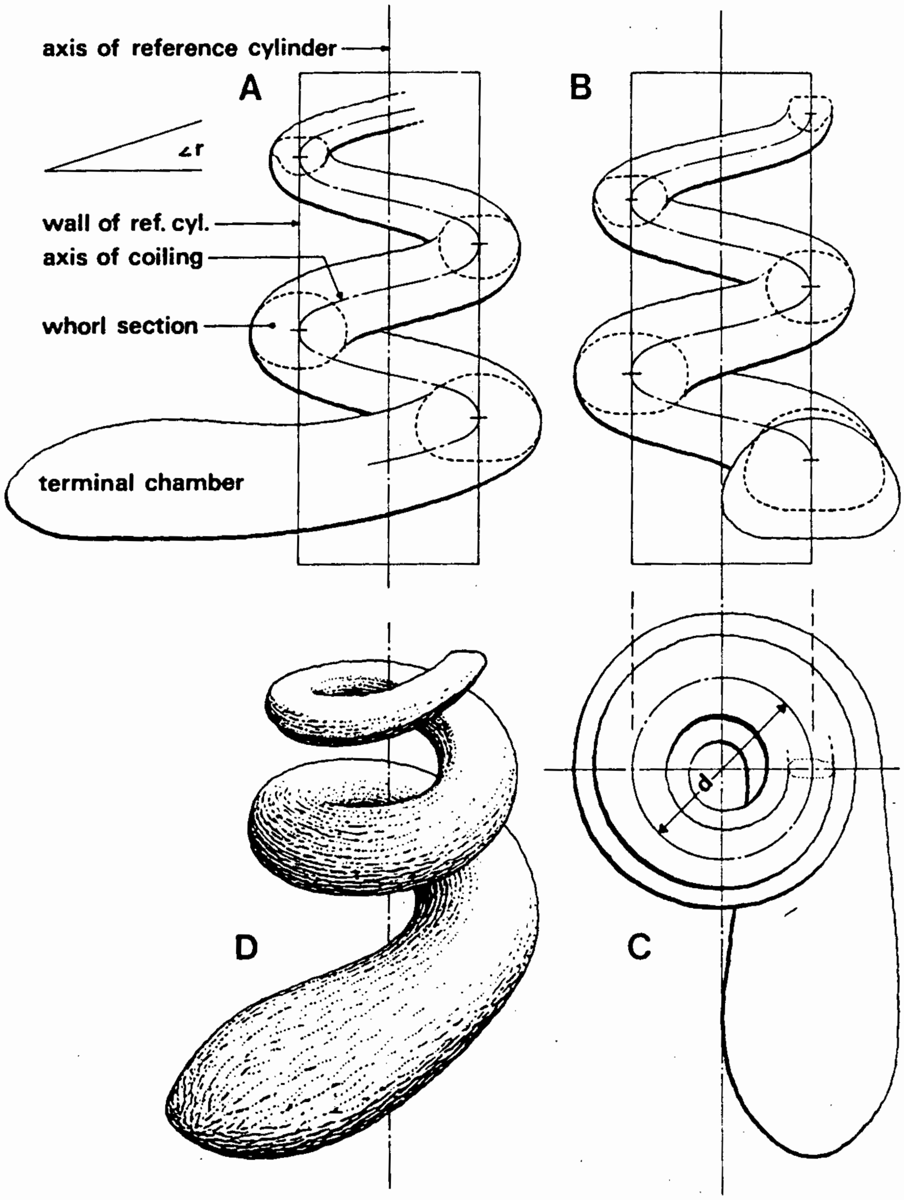


FIG. 66 Geometry of helical burrow casts from the Teekloof Formation. Three elevations (A, B, C) and a perspective view (D) of a typical helical burrow cast with a ramp angle (r) of 18 degrees and a reference cylinder diameter (d) of 25.5 cm.

declination of coiling (ramp angle) is consistent within any single burrow but between those recorded it ranges from 10 to 32 degrees. Declinations of the few upper shafts that were found in situ are between 30 to 35 degrees.

The more resistant calcified burrow casts display a distinctive surface texture consisting of numerous parallel straight to slightly curved ridges running tangentially up the outer wall of the spiral section and forming a chevron pattern on the sides and top of the terminal chamber (Fig. 70b). On the underside similar ridges trend along the long axis and are intermeshed with numerous thin filamentous casts resembling rootlets (Fig. 67). These are interpreted as casts of scratches made by the digger whilst excavating its burrow.

A few of the burrows are excavated into sandstone and filled with less resistant mudrocks, others are excavated into mudrocks and filled with siltstone, parts of which are cemented with palaeopedogenic carbonate (Figs. 68 and 69). Most, however, are excavated into mudrocks and filled with fine-grained sandstone (Figs. 29, 30, 70a and 70b) of crevasse-splay origin.

The sedimentological sequences at the helical burrow localities in Teekloof Pass and Reiersvlei areas are similar despite differences in cast lithology (see Fig. 71). Both sequences were deposited on proximal floodplain areas between well-vegetated meanderbelt rise and the parched playa-type depressions in the axial floodbasin. The flat non-erosive bases of crevasse-splay sandstones are often in continuity with burrow casts and provide a measure of the original depth of burrowing, which in these areas is 1 - 1.25 m. Assuming that the animal would not have tolerated water seeping into its terminal chamber the complete casts give an indication of minimum depth to the palaeo-watertable.

The burrow casts were formed by passive rather than active means, that is, there was no backfilling done by the digger, the infilling being entirely due to geomorphic processes. The sharpness of contacts between cast and host rock, as well as the contrasting colours, textures and weathering patterns and the presence of fossils lying at discordant attitudes all contribute to the distinction and recognition of vertebrate burrows.

FIG. 67 Sole impression of scratch marks on the underside of a terminal chamber at the Reiersvlei burrow site. The larger ridges are interpreted as casts of beak scrapes, the smaller chevron-shaped ones, as claw scratches. The interlinking "tubules" are probably rootcasts. Scale in cm.

FIG. 68 In situ spiral of a helical burrow-cast at the Reiersvlei locality. The cast is composed of resistant, brown-weathering, calcareous siltstone in a grey siltstone host matrix. Note the plano-convex cross-section of the upper whorl, becoming larger and more elliptical round the second whorl. The ramp angle is 20 degrees and matchbox 5 cm long.

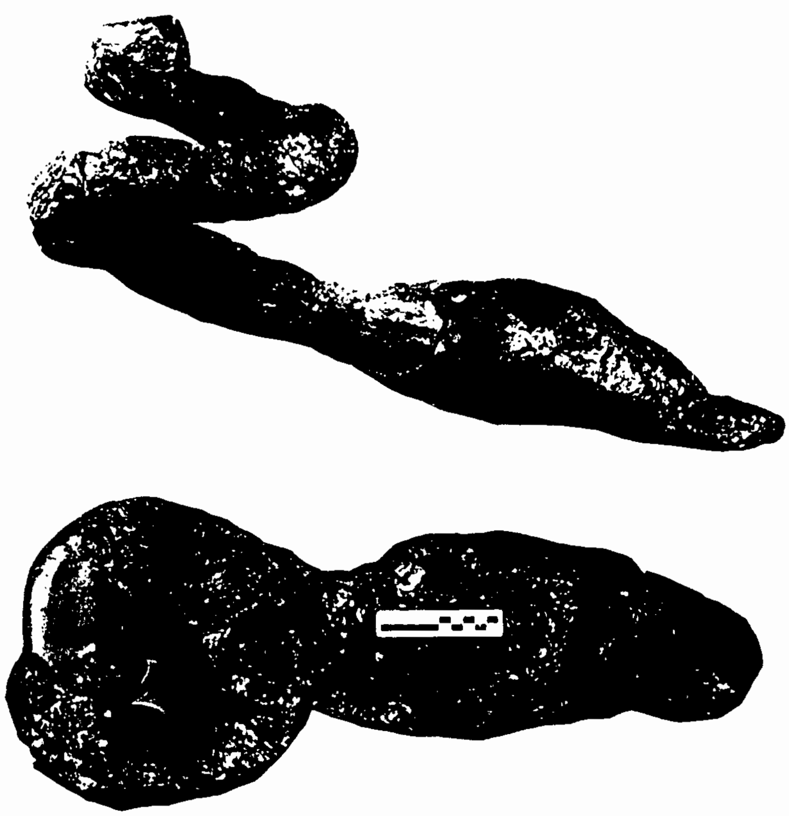
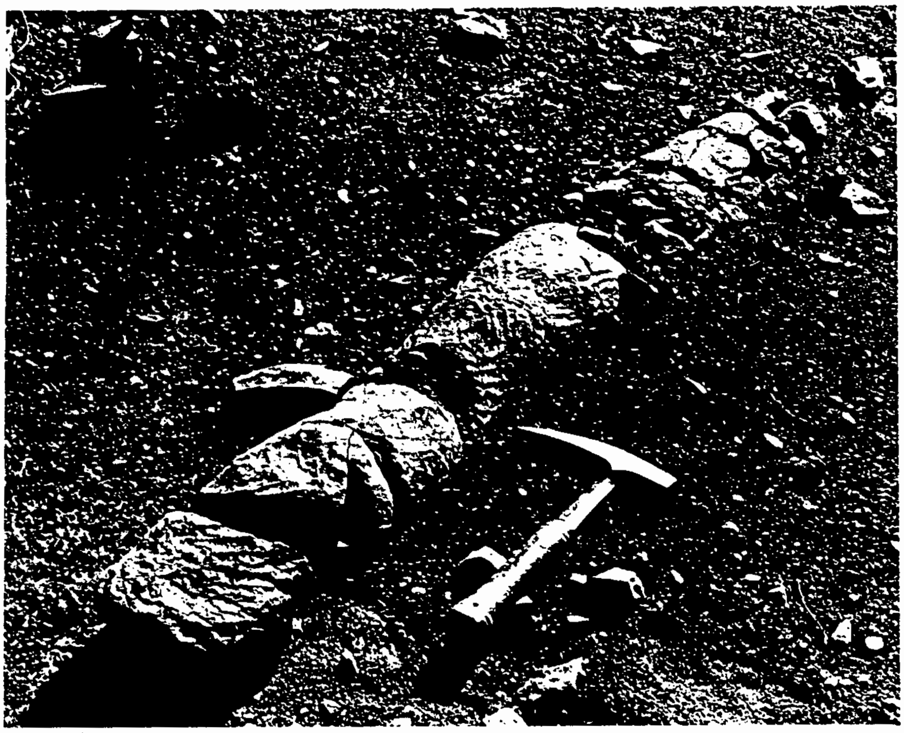


FIG. 69 Near complete calcretised helical burrow cast from Leeukloof L3 locality (see Fig. 9). Note the flat "meniscus" of the terminal chamber infill and the consistant ramp angle through the two dextral whorls. Scale in cm.

FIG. 70 (A) Sandstone-filled decline burrow with terminal chamber exposed at Leeukloof L2 locality (see Fig. 9). Outcrop in top right-hand corner is the crevasse-splay that infilled this burrow.
(B) Sandstone-filled decline burrow on Dunedin (see Appenidix Fig. 21) showing a chevron pattern of ridges interpreted as casts of claw and beak scrapes of a dicynodont.



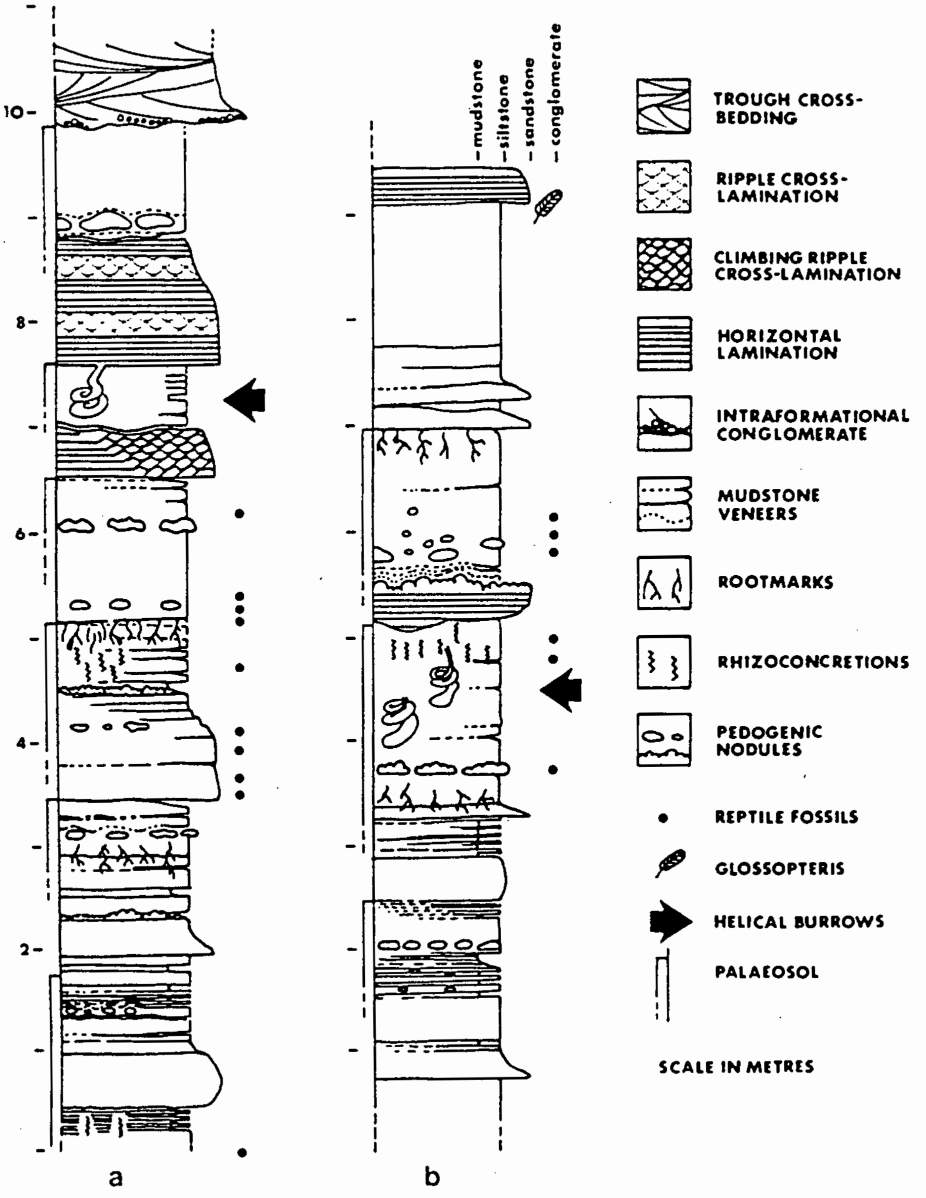


FIG. 71 Sedimentological logs of the Teekloof Pass (a) and Reiersvlei (b) helical burrow localities.

Articulated and scattered skeletons of *Diictodon* and *Oudenodon* have been found in the terminal chambers of both types of burrows (Fig. 70), some being complete curled-up skeletons (Fig. 72), others being paired (Fig. 73) and one containing three juvenile skeletons lying side by side (Fig. 74).

The rare and taphonomically anomalous occurrences of paired *Diictodon* skeletons in "inter-curled" and "intertwined" disposition is interpreted as a record of death and burial of the burrowers within their underground burrow. At the Teekloof Pass burrow locality several curled-up skeletons (taphonomic class A) were recovered as well as the two intertwined skeletons shown in figure 63. The latter were found lying across the bedding planes, at an angle identical to the ramp angle of a nearby sand-filled burrow cast (Figure 29). Although not clearly defined, it is likely that they were entombed in the spiral of their burrow by a sudden collapse brought on by flash flooding.

It is clear, therefore, that *Diictodon*, *Oudenodon* and probably other small dicynodonts excavated tunnels into the floodplain soils probably to hibernate or aestivate during periods of climatic stress. Although each burrow is a separate entity several were dug in close proximity implying gregariousness of the living community. Thus pairing and communal denning behaviour in *Diictodon* was probably the rule rather than the exception and explains the preservation of some of the taphonomically anomalous "intertwined" and "intercurled" class A and B *Diictodon* skeletons collected from the study area.

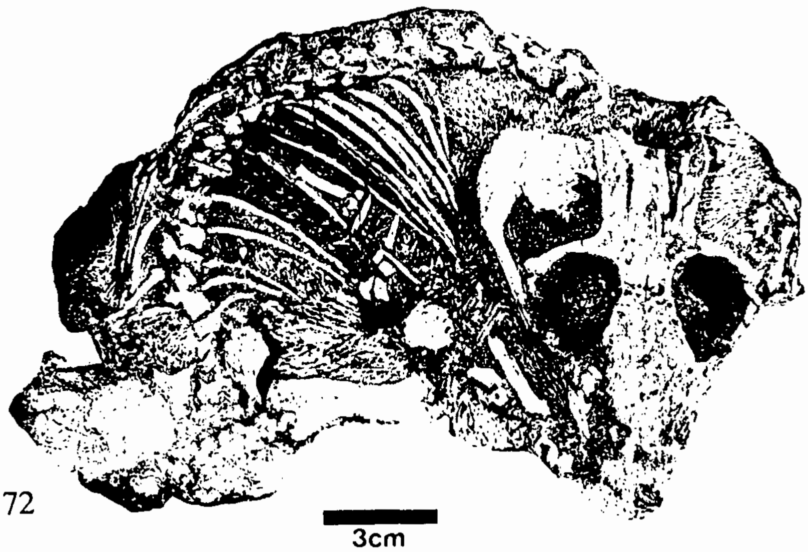


FIG. 72

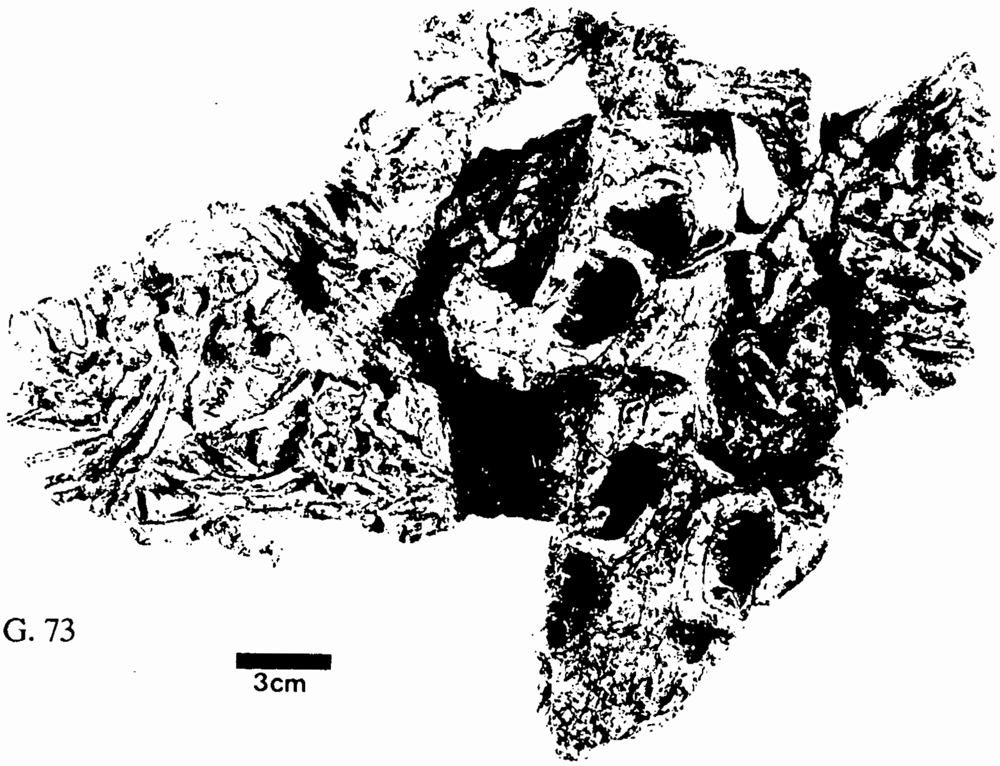


FIG. 73

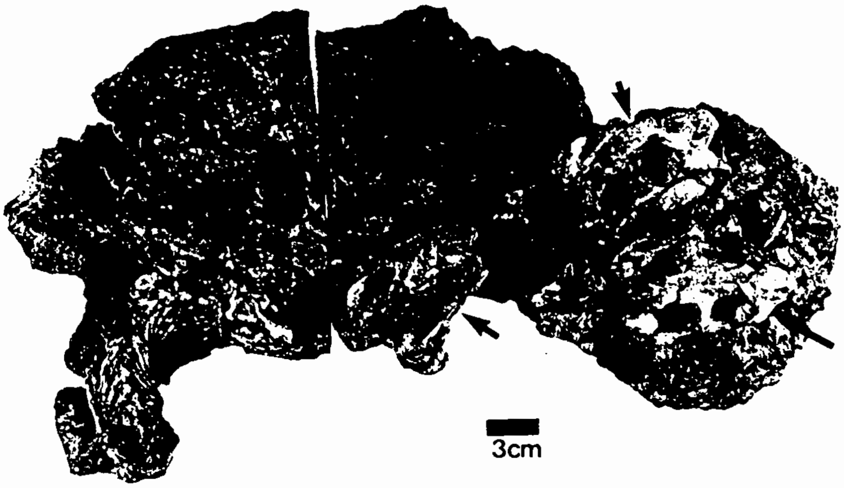


FIG. 74

FIG. 72 Prepared curled-up *Oudenodon* skeleton from the terminal chamber of a sand-filled burrow on Dunedin (Locality 22 of Appendix Fig. 21).

FIG. 73 Two disarticulated but still associated *Diictodon* skeletons most probably preserved in a burrow on the farm Amandelboom (see K6941 Appendix Fig. 20 for locality).

FIG. 74 Three "intertwined" articulated juvenile *Diictodon* skeletons (skulls arrowed) preserved within metres of the decline burrow shown in Fig. 70 (see K7028 of Appendix Fig. 20 for locality).

5. INTEGRATING SEDIMENTOLOGY, PEDOLOGY AND TAPHONOMY TO RECONSTRUCT GEOMORPHIC PROCESSES AND CLIMATE DURING THE ACCUMULATION OF THE TEEKLOOF FORMATION

Vertical and lateral variations in the volumetric proportions and packing of the different rock types making up the Teekloof succession were ultimately caused by pulses of basinal subsidence (Bridge and Leeder, 1979; Allen, 1974a, b; Smith, 1980) and their effect on

- local sedimentation rates and gradients,
- regional floodplain accretion rates, and
- the size and migration behaviour of drainage nets and fluvial channels.

These three geomorphic variables had a profound influence on the landscape, its topography, soils and the flora and fauna that it supported. The aim of this chapter is to integrate the information gathered on sedimentary, pedogenic and taphonomic processes in the previous chapters and use it to interpret and describe the major landscape features, the main geomorphic processes and the prevailing climatic conditions during accumulation of the Teekloof Formation.

5.1. SCALE OF THE FLUVIAL SYSTEMS

The macrostratigraphic panel sections of the Teekloof Formation exposures along the Nuweveld escarpment (Appendix Figs 4.A and 4.B) offer an opportunity to measure changes in the scales of the fluvial channels through the succession as well as changes in the "channel density" and "connectedness" (Bridge and Leeder, 1979). The channel density is an estimate of the number of fluvial channels per unit area of the alluvial plain. In the sandstone-rich Poortjie member the channel density was in the order of 1 active meanderbelt every 10 km along the length of the alluvial plain, in the foreland of the Gondwanide mountain chain. In the overlying mudrock-dominated Hoedemaker member the channel density dropped to 1 meanderbelt every 40 to 60 kilometres. The succeeding Oukloof member was again well channelized but not to the extent of the Poortjie, with meanderbelts every 20 km or so. The Oukloof meanderbelts were narrower (2 - 3 km) and contain fewer multistoried channel deposits. Channels become scarce again in the Steenkampsberg member overlying the Oukloof but are more abundant than in the Hoedemaker, with a meanderbelt every 30 - 35 km.

Between the meanderbelt ridges, which were the only positive relief features on the landscape, the floodplains and floodbasins contained numerous standing water bodies which changed in size and permanence through time. Throughout the deposition of the Teekloof Formation, as channel density increased, the size and permanence of floodbasin lakes decreased. The significance and possible tectonic control over these changes in channel density are discussed later in this chapter.

The three-dimensional exposures of exhumed sandstone bodies on the farms Reiersvlei and Leeukloof provide a good opportunity to directly measure the dimensions of some of the palaeotopographic features. Figure 75 shows three stages in the genesis of the present Reiersvlei sandstone outcrop and the predicted changes in measurable bankfull width immediately after abandonment, after burial and after exhumation. From this model the measurable features of the outcrop can be assessed as to their usefulness in reconstructing the morphology and hydrology of the original river.

The most reliable palaeomorphological feature is the centreline of the abandoned channel-fills. From this, confident direct measurements of meander wavelengths, amplitudes, radii of curvature and sinuosity can be made (see Table 7). The Reiersvlei meanderbelt was in the order of 3 000 m wide containing a channel with an average sinuosity ratio of 1.65 (high sinuosity) and an average radius of curvature of 600 m. The meander wavelengths ranged from 2 400 - 4 000 m with a mean of 3 200 m.

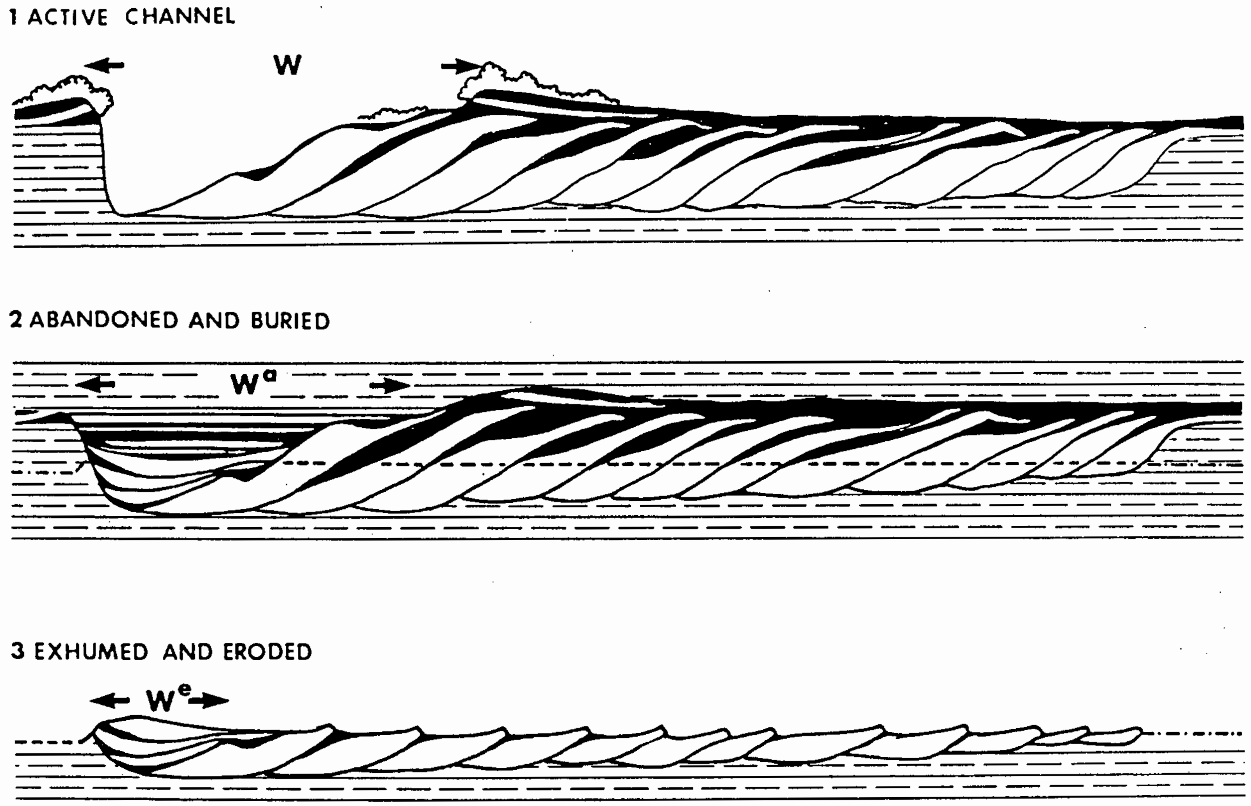


FIG. 75 Schematic model for the genesis of the Reiersvlei sandstone outcrop illustrating changes in measurable bankfull width (W) with abandonment and burial (Wa), exhumation and erosion (We). Note the channel-fill mound and remnant "accretion ridges" on the eroded sandstone surface.

Bankfull channel widths and depths cannot be reliably measured from outcrop due to the complete removal of an unknown thickness of topstratum fines. However, these parameters may be estimated through the substitution of more reliable measurements into empirically derived hydrological equations (Table 8).

Jackson (1978), Ethridge and Schumm (1978) and, more recently, Bridge (1985) and Miall (1985) express reservations as to the application of empirical relationships that have been developed to quantify morphology and flow characteristics in modern streams to the reconstruction of morphology and hydrology of paleochannels. A major shortcoming of this approach is the lack of detailed information on large river systems, especially those on actively aggrading coastal plains. Confidence in the results may be improved by initially assessing the preservation potential of various palaeomorphological features in order to isolate those on which to base quantitative palaeohydraulic calculations. However, the complexity of processes and response in modern meandering streams .... "does not encourage prospects for more precise methods" (Jackson, 1978). Nevertheless, there are some fundamental relationships between channel morphology and its flow parameters that may be used to make some worthwhile calculations of the palaeohydrology of the Reiersvlei sandstone.

Table 7 summarizes the dimensions of measurable palaeomorphological features of the Reieresvlei sandstone. The width of the eroded channel-fill ridge is in the order of 200 m. An estimate of the former bankfull width may be made using Leopold and Wolman's (1960) relationship between bankfull width and meander wavelength (see Table 8). The latter may be confidently measured as ranging from 2 400 - 4 000 m which when substituted into the equation produces a range of former bankfull widths from 208 to 346 m, averaging 277 m.

Moody-Stuart (1966) stated that the bankfull widths of meandering rivers are in the order of 1.5 times wider than the lateral accretion units preserved in their point-bar deposits. Erosion of the surface of the Reiersvlei sandstone makes it impossible to directly measure the full horizontal extent of lateral accretion

PALEOMORPHOLOGICAL PARAMETERS (MEASURED FROM OUTCROP)		RANGE (m)	AVERAGE (m)
Width of channel-fill	(eroded)	100-300	200
Meander wavelength	(Lm)	2400-4000	3200
Meander amplitude	(Am)	900-1450	1183
Radius of curvature	(Rm)	400-825	600
Sinuosity ratio	(P)	1.5-1.8	1.65
Meanderbelt width (estimated sand body width)	(Wm)	-	3000
Depth of channel (vertical thickness of eroded epsilon units, D^e)		3.5-7	5.25
Slope of point bar surface (coarse member)		10^o-15^o	12.5^o
Horizontal extent of accretion surfaces (eroded)		150-225	187

TABLE 7 List of measured dimensions of the "Reiersvlei Sandstone" on Reiersvlei.

PALEOHYDRAULIC PARAMETERS (CALCULATED)	SOURCE	RANGE	AVERAGE
Bankfull channel width (W)			
$W^{1.01}$ = Lm/10.9	(Leopold & Wolman 1960)	208-346	277 m
W = 1.5 (Horiz. extent of accretion surfaces)	(Moody-Stuart 1966)	225-337	270 m
Bankfull channel depth (D)			
$D^{1.54}$ = Lm/74.1	(Collinson 1978)	9.6-13.3	11.5 m
D = D^e x 0.585/0.9	(Ethridge & Schumm 1978)	6.7-13.3	10.0 m
Cross-sectional area (A)			
A =D/2 (2W-Horiz.ext.acc. surf.)	(Gardner 1983)		2018 m^2
Average bankfull discharge (Q)			
$Q^{0.5}$ = Lm/30	(Dury 1965)	1943-5418	3467 m^3/s
$Q^{0.5}$ = Am/14.2	(Foweracker 1963)	1223-3177	2114 m^3/s
Mean annual discharge (Qm)			
$Qm^{0.46}$ = Lm/106	(Leeder 1973)	330-1003	617 m^3/s
Qm = $W^{2.43}/18F^{1.13}$	(Schumm 1972)	778-959	851 m^3/s
Mean annual flood (Qma)			
Qma = $16(W^{1.56}/F^{0.66}$	(Schumm 1972)	8688-17024	12176 m^3/s
Average Velocity (V)			
V = Q/A		0.61-1.58	1.05 m/s
Width/Depth ratio (F)		21.6-26.0	24
Rm/W ratio		1.58-4	2.8
Rate of Meander migration (M)			
M = $0.10(Rm/W)^{2.05}$ for $(1.3<Rm/W<2.9)$	(Hicken & Nanson 1975)	0.6-0.85	0.72m/yr
Slope (S)			
S = $0.00146/Q^{0.25}$	(Lane 1937)		.00022

TABLE 8 Calculated palaeohydrological parameters of the Reiersvlei Sandstone.

surfaces but in nearby cliff sections on Waterval, where the topstratum beds are fully preserved, the accretion units are 150 - 225 m wide (See Appendix Section 5). Using Moody Stuart's correction factor, the former channel width would have ranged from 225 to 337 m, averaging 281 m, some 42% wider than the measured remnant channel-fill.

Calculated bankfull depths range from 6.7 m to 13.3 m (see Table 8) with an average of around 10 m and, again in accordance with figure 75, they are three to five times greater than the remnant coarser member thicknesses. Confidence in these estimates is raised by the closeness of values obained using three input variables into four different equations (see Table 8).

The removal of up to 7 m of upperpoint-bar deposits during exhumation of the Reiersvlei sandstone may be an over estimation although recent studies of modern muddy, fine-grained point-bar deposits in bends with ratios of channel curvature to stream width (Rm/w) comparable to the Reiersvlei meanders, shows the upperpoint-bar fine member to be from three to five times thicker than the coarse member (Jackson, 1981). It is possible that a similar situation existed in the Reiersvlei point-bars and that under normal flow conditions silt and mud accumulated on the middle and upper point-bar. During flood events, the muds were scoured and a layer of sand deposited on the gently sloping (10 - 15 degree) bar surface. Recent denudation of the middle and upperpoint-bar deposits has removed most of the mudrocks and has reduced the more resistant sandstone beds to remnant "accretion ridges" (Fig. 75).

The dimensions of the Reiersvlei meanders are considerably larger than the numerous palaeochannel measurements listed by Ethridge and Schumm (1978) and are barely matched by the meandering palaeochannel described by Gardner (1983) from the Carboniferous of Kentucky. They are, however, comparable to the modern Mississippi (Fisk, 1944, 1947) and the meanderbelt geometry of this river, described by Jackson (1978), provides a reasonable modern analogue to the ancient Reiersvlei system.

The low-sinuosity distributary streams that drained away from the main channels were generally narrow (<50 m wide) and deeply incised into the floodplain. The basal coarse member of these channels is represented in the Teekloof strata by narrow "shoestring sandstones". Exhumed shoestring sandstone that outcrop lateral to the Leeukloof and Reiersvlei meanderbelt are in the order of 50 m wide and 5 m thick giving width/depth ratios of approximately 10:1. There is no evidence of lateral accretion structures within these sandstones and it appears that the original stream fully filled the incised channel at least during peak flood.

Crevasse-splay fans associated with the Reiersvlei meanderbelt extended up to 1 500 m into the floodplain forming a continuous ephemeral stream sand sheet in the order of 70 - 100 m wide. The crevasse channels were generally wide and shallow and probably formed an anastomosing network. The preserved dimensions of individual splay channels in the Leeu River section on Amandelboom (Appendix Fig. 22) is in the order of 40 m wide by 3 m deep. It is possible that these low sinuosity distributary channels flowed from the margins of the crevasse-splay fans and that they in fact represent distal splay channels (Smith, N.D., 1989).

5.2. PALAEOHYDROLOGY AND MIGRATION BEHAVIOUR OF THE REIERSVLEI MEANDERBELT

Using a calculated average width/depth ratio of 24 for the Reiersvlei palaeochannels, the mean annual discharge and mean annual flood may be derived from Schumm's (1972) equations (see Table 8) to give values of 851 cubic metre/s and 12 176 cubic metre/s, respectively. More direct and, perhaps more confident calculations of discharge using meander wavelengths and amplitudes (Dury, 1965; Foweracker, 1963), give values for average bankfull discharge ranging from 2 100 - 3 400 cubic metres/second. Discharges of the same order of magnitude are recorded in the Lower Mississippi River (Fisk, 1947).

Applying Gardner's (1983) derivation of the cross-sectional area (A) of an abandoned channel (Table 2) and substituting it into the continuity equation Q = VA (Leopold *et al.*, 1964), where Q is the average bankfull discharge, estimates of average velocities (V) can be calculated for the Reiersvlei meanders. Velocities between 0.6 and 1.5 m/s are comparable to those of modern relatively large, wide moderate-to-high sinuosity systems such as the Murrumbidgee River in Australia (Schumm, 1968; Ethridge and Schumm, 1978).

Lane (1937) empirically quantified a relationship between average discharge and the slope of stable channel beds in erodable materials (Table 8) which, when used to estimate the slope of the original Reiersvlei River, gives a figure of 0.0002. This extremely low gradient is the same as the stream -length averaged gradient across the 500 km wide Indo-Gangetic alluvial plain (Sehgal and Stoops, 1972).

Combining palaeocurrent data with the pattern of "accretion ridges" on the eroded Reiersvlei sandstone allows previous channel curvatures to be traced to gain some indication of migration behaviour (Hickin, 1974; Hickin and Nanson, 1975). Figure 76 illustrates initial, intermediate and final stages in the development of the Reiersvlei point-bars, highlighting the complicated truncation, erosion and superposition of accretion units within the expanding meanders. Recent studies have demonstrated that the ratio radius of curvature to bankfull channel width (Rm/w) is an important parameter controlling the rate of migration (Hickin and Nanson, 1975) and the distribution of depositional facies in different parts of the bend (Jackson, 1976, 1981). The Helm bend of the Lower Wabash river in Indiana (Jackson, 1976) has a similar Rm/w ratio (2.7) and a comparable migration history (ie. expansion with increase in channel curvature) to Reiersvlei point-bar 1. Within the Helm bend the "fully developed depositional facies", where flow velocities and mean grain sizes increase from the inner toward the outer banks, is positioned immediately downstream of the meander apex.

This may account for the observed thickening and coarsening of Reiersvlei "active" channel-fill deposits forming the low scarps around the apex of the

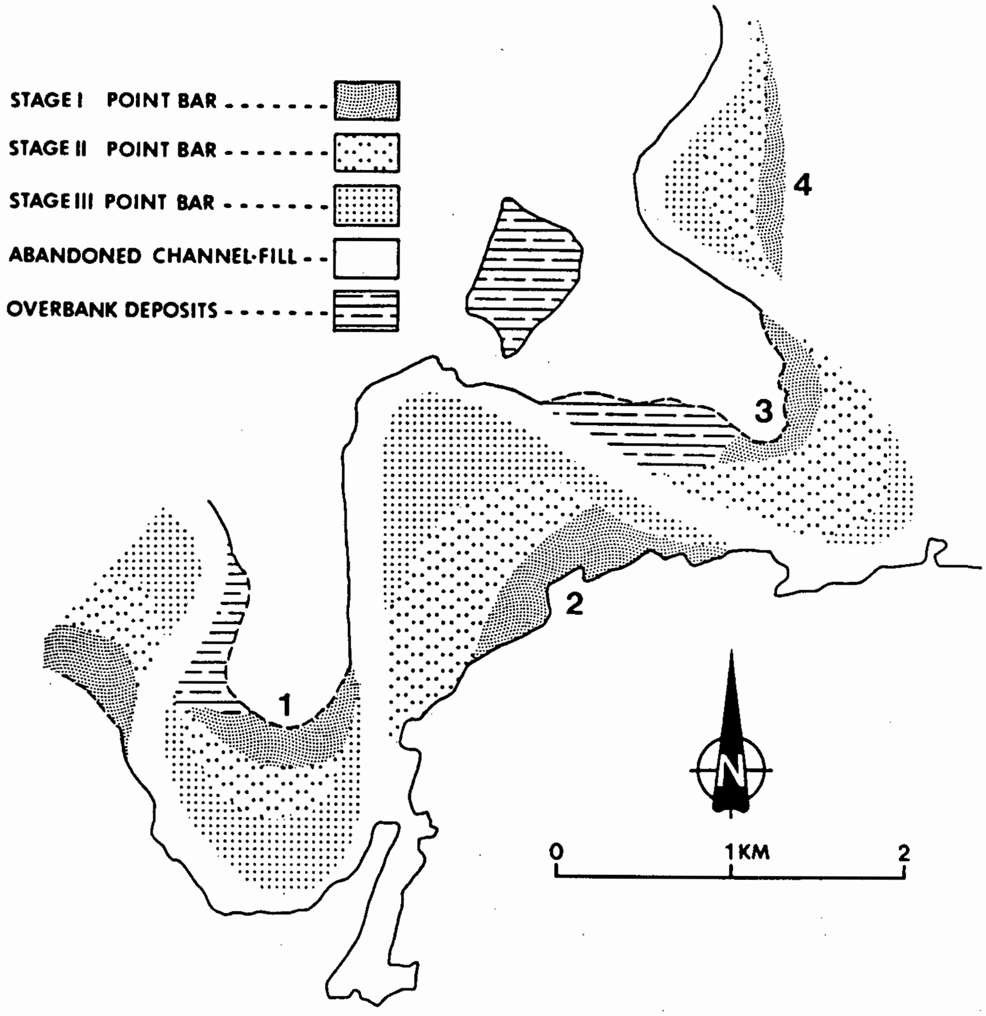


FIG. 76 Migration behaviour of the Reiersvlei meanders. Three arbitrary migration "stages" compiled from palaeocurrents and accretion topography demonstrate a general tendency for expansion, increase in curvature and, especially with point-bar 3, slight upstream translation. Note the complicated truncation and superposition of successive point-bar deposits.

meander bends (Fig. 22). Another characteristic of the fully developed zone is its increased preservation potential for scroll bars (Jackson, 1976) possibly explaining the apparent concentration of "accretion ridges" on downcurrent portions of the Reiersvlei point-bars.

An estimate of the rate of lateral migration (M) can be gained from Hickin and Nanson's (1975) equations (Table 8) using the Rm/w ratio. Radii of curvature are measurable directly from the outcrop whereas bankfull width must be calculated to compensate for the severe erosion of the channel-fill. Migration rates for the Reiersvlei point-bars range from 0.6 to 0.85 m per year, which, over the reconstructed migration distances (Fig. 76) and assuming a long term constancy, gives an estimated 1 - 1.5 x 1 000 years between avulsion events. Leeder (1978) constructed quantitative models for alluvium accretion based on observations of modern floodplains, such as the Mississippi (Fisk, 1944), Brazos (Bernard *et al.*, 1970) and Rufiji (Anderson, 1961) and concluded that a realistic mean avulsion periodicity for these rivers is 1 - 2 x 1 000 years, a figure comparable to the above.

On an aggrading alluvial plain with no interfluve ridges, there would have been few physical barriers to meander migration. Within the Reiersvlei river system, net-sediment accumulation in the meanderbelt would have exceeded that of the interfluve basins, leading to the formation of a meanderbelt ridge. At some point the interchannel gradients became more favourable than the downstream slope on the channel bed (ie. 0.00022, see Table 7) thus priming the system for an avulsion event. Avulsion was possibly triggered, during peak flood, by the breaching of a levee wall around a tightly curved meander, followed by rapid downcutting as flood waters flowed down the flanks of the meanderbelt ridge into the floodbasin. The resultant crevasse channel, if sufficiently incised, could capture the thalweg to effect a permanent diversion causing abandonment of the downstream meanderbelt.

5.3. TIME RESOLUTION AND DEPOSITIONAL HISTORY OF THE LEEUKLOOF PORTION OF THE REIERSVLEI MEANDERBELT

Figure 77 is a graphic reconstruction of a series of successive palaeolandscapes that existed before, during and after the deposition of the Reiersvlei sandstone on the farm Leeukloof. It illustrates how good 3-dimensional exposures may be used in reconstructing palaeolandscapes and how detailed the resolution of such landscapes can be over an area of some 25 square km.

The 45 m succession began with the sudden arrival of a major channel followed by a period of lateral migration and abrupt abandonment (meanderbelt 1 of Fig. 77) leaving behind an alongate sand body some 6 km wide, 8 - 10 m thick and at least 35 km long. The preserved portion of this sand body forms the lowermost strata exposed on Leeukloof and is not yet fully exhumed.

There followed an extended period of floodplain aggradation over this area (Fig. 77.2) which completely buried the sand body beneath proximal floodplain deposits. A network of narrow, mud-banked ephemeral streams drained the area leaving behind straight to slightly sinuous "shoestring"-shaped sand bodies.

Vegetation stabilized the proximal floodplain promoting soil formation which reached fairly advanced stages of maturity. Comparison of the palaeocalcrete glaebules in this succession with those of modern studies show that they could have taken up to 10 000 years to reach this stage of maturity (Reeves, 1970; Williams and Polach, 1971). This indicates that the alluvial plains on which these soils were forming remained unflooded or at least free from significant sedimentation for up to 10 000 years (Leeder, 1975). This could have arisen either because the rivers shifted about on the plains (Allen, 1974a; Leeder, 1975; Bridge and Leeder, 1979; Kraus and Bown, 1986) or because of cyclical river dissection-aggradation coupled with lateral movements (Allen, 1974b). In this succession the common preservation of single-storied channel sandstones is interpreted as representive of avulsion-controlled channel deposits under the

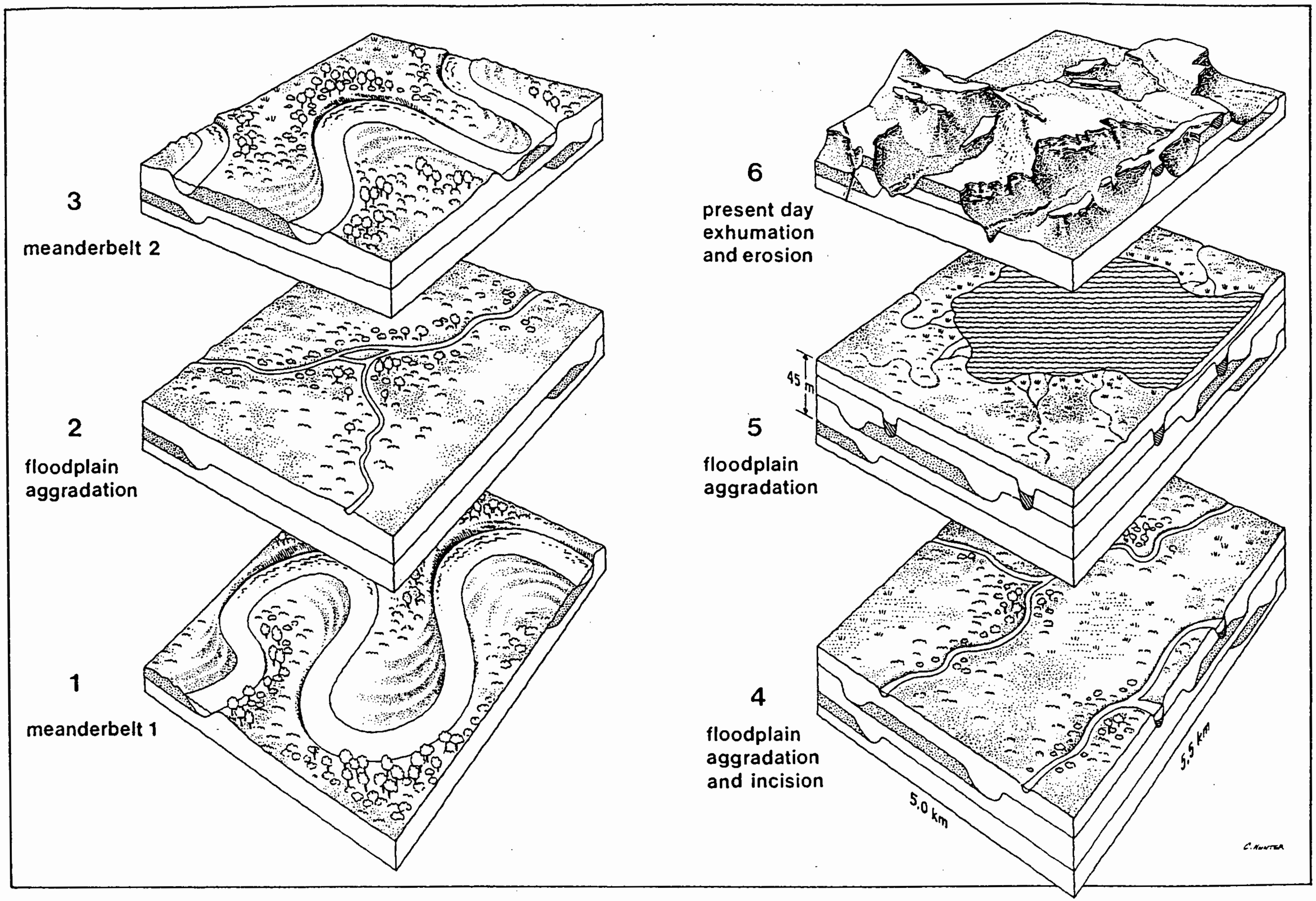


FIG. 77 Successive palaeolandscapes used to reconstruct the depositional history of the 45 m rock succession exposed on Leeukloof 402.

influence of high basinal subsidence rates. Thus, the most mature palaeosols (stage 3 of Leeder, 1975) developed on the parts of the alluvial plain that were most distant from the trunk channels and those channels re-occupied the area only after an absence of at least 10 000 years (Bridge and Leeder, 1979).

Seasonal rainstorms in the basin and provenance areas caused the major meandering rivers to burst their banks and inundate the parched floodplains. These essentially catastrophic events accounted for the bulk of floodplain sedimentation. It is clear from the advanced maturity and thickness of some of the palaeosol profiles in this interval that, for periods up to 10 000 years, the average floodplain accretion rates did not exceeed 2 mm/year (Leeder, 1975).

Mammal-like reptile carcasses were thus allowed ample time to decompose, desiccate and disarticulate before being scattered by sheet floods. The increased proportion of weathered to unweathered fossil bone in these proximal floodplain deposits suggests that skeletal elements spent between 2 and 20 years on the floodplain surface before becoming completely buried. During this period a layer of 40 mm of floodplain silts could have accumulated around and over these elements. This would, therefore, favour the preservation of the smaller vertebrate skeletons such as *Diictodon*, *Emydops*, *Pristerodon* and *Cistecephalus* rather than larger ones such as *Endothiodon*, *Parieasuchus* and *Gorgonops*.

After some 10 - 15 000 years, the main channel once again arrived in this part of the floodplain (meanderbelt 2 of Fig. 77). It eroded deeply into the floodplain soils and then began to migrate. The river meanders expanded outwards and downstream (towards the north-east) at a maximum rate of 0.85 m per year (Hickin and Nanson, 1975) for at least 1 500 years before an upstream avulsion again diverted its flow elsewhere.

The 3 000 m wide abandoned sand body then became buried beneath channel-bank and proximal floodplain fines containing "shoestring" distributary channels, crevasse-splay sandstones and abundant therapsid bones (Fig. 77.4 and Appendix Fig. 8). Floodplain accretion rates in this interval are estimated to have been relatively high, in the order of 4 mm/year for at least 40 000 years. The increased accretion rates prevented the soils from forming indurated duripan horizons. Later, sedimentation in this area was of the distal floodbasin type (Fig. 77.5) with accretion rates of less than 1 mm/year. Palaeosols were poorly developed due to the high water table and semi-arid climate. Horizons of gypsum rosettes and "desert rose" crystals formed near the surface (Appendix Fig. 8). Bones were rarely incorporated into the sediment because of the general hostility of the environment as well as the very slow rates of burial.

The problems of time resolution in the stratigraphic record are well demonstrated by the Leeukloof section. Absolute time taken to accumulate a certain stratigraphic interval may be estimated by two methods. Firstly, an average time taken to accumulate a metre of rock may be estimated by dividing the total time taken for deposition of the entire succession (determined from radiometric age dating or biostratigraphic correlation) by the average thickness of the succession in metres. The second method uses the number and maturity of palaeosols to estimate the minimum amount of time that no significant sedimentation was taking place on the floodplains. The discrepancy between the results of the first and second method is, therefore, an indication of how much time is not represented by either sediments or palaeosols which in effect means erosion or periods of landscape degradation.

Applying the first method, the average rock accumulation rate and the average time taken to accumulate the section in question may be calculated. Obviously the accuracy of such estimates depends on the accuracy and number of absolute age dates throughout the succession as well as the homogeneity of the sedimentary pile and the absence of large scale erosional or non-depositional surfaces. Applying this method to the 45 m Leeukloof succession, using the 240 Ma to 220 Ma absolute age dates available for deposition of the 2 000 m of Lower Beaufort strata in the south-western Karoo (Turner, 1979) gives an average rock accumulation rate of 10 000 years per metre, or 450 000 years for the Leeukloof section. To gain an estimate of the average rate of sedimentation, the amount of time that is not represented in the stratigraphic succession has to be estimated and included in the calculation. This is the point at which palaeosols can play an important role in that they indicate periods of non-deposition that are otherwise not represented in the rock record.

The 45 m Leeukloof section contains seventeen Stage 3 palaeosol profiles (Appendix Fig. 8) which each represent 10 - 14 000 years of negligible floodplain accretion and which in themselves account for some 238 000 years out of the 450 000 years that the succession took to accumulate.

From this an estimate of the rate of floodplain sedimentation can be made by first applying a compaction-correction factor of 33% (Allen, 1986) to compensate for the lithification of alluvium (ie. 60 m of alluvium) and a stasis-corrected depositional period of (450 000 - 238 000) 212 000 years. This gives an average floodplain sedimentation rate of 0.28 mm/year. The same calculation, using the original figures that were not stasis-corrected, gives an average floodplain accretion rate of 0.13 mm/year. Similar calculations have been made for the White River group, South Dakota (Retallack, 1983b) with similar results (0.023 mm/year corrected using palaeosols to 0.47 mm/year) whereby the stasis-corrected sedimentation rates were 20 times larger than rates based on radiometric or palaeomagnetic data. The fact that the Leeukloof measurements are relatively close (factor of 2 discrepancy) is interpreted as an indication that the Lower Beaufort succession is relatively complete with no large hiatuses or periods of regional landscape degradation.

It is interesting to apply the stasis-corrected sedimentation rate, calculated for the Leeukloof section, to the entire Lower Beaufort 2 000 m rock succession (taking into account the compaction factor). This gives a figure of 1 860 000 years for the sedimentation of the Lower Beaufort which is some 10.75 times shorter than the total time represented based on radiometric dating techniques. In the absence of major degradation surfaces the rest of the time may be accounted for in floodplain stasis which allowed sufficient time for pedogenesis and, of course, organic evolution of the flora and fauna.

Kraus and Bown (1986) argue that, although the rock record contains numerous gaps in the sedimentary record due to non-deposition and erosion, the fossil assemblage on the other hand may contain an attritional accumulation that was incorporated into the floodplain soils throughout the period of non-deposition. Thus the fossil record may, in these instances, be more complete than the rock record.

5.4. PALAEOCLIMATIC INTERPRETATION OF THE TEEKLOOF FORMATION

5.4.1. Palaeoclimatic Interpretation of the Sediments

Suites of sedimentary structures in the channel and overbank deposits reflect highly fluctuating hydrodynamic conditions characteristic of arid zone rivers. These include the following -

1. Predominance of plane bedding with parting lineation and crescentic scours around clay pebbles. This is a characteristic of shallow water flash-floods in semi-arid to arid zone rivers (Billi and Tacconi, 1985).
2. Upward transitions from horizontal lamination to climbing ripple-cross-lamination indicative of rapid sedimentation of sand and silt from rising flash floods (McKee *et al.*, 1967).
3. Silt drapes over rippled surfaces are an indication of abrupt deceleration of flow following a short-lived peak discharge (Picard and High, 1973).
4. Post-flood emergence and desiccation of scroll-bar, levee and crevasse-splay surfaces caused case-hardening and mudcracks in the silt and mud drape which later became filled with aeolian sand (Stear, 1983).
5. The irregularity of lateral accretion ridges on the exhumed point-bars reflects highly fluctuating discharge typical of large rivers on semi-arid alluvial plains such as the Murrumbidgee (Schumm, 1968).

5.4.2. Palaeoclimatic Interpretation of the Palaeosols

Palaeosols in the Interchannel Facies Association are the product of prolonged interaction between the parent alluvium and the prevailing climate in the presence of both plant and animal life. Through comparison with modern soils it is possible to make some broad generalizations about the climatic conditions under which the fossil soils were formed.

1. The various types of calcium carbonate glaebules in the A and B horizons of the Teekloof palaeosols are a good indicator of a semi-arid climate. They are closely comparable in scale,surface texture, macrostructure and composition to many Quaternary pedogenic calcretes and carbonate - bearing soils (Netterburg, 1980; Reeves, 1976; Gile *et al.*, 1966). Today calcretes are most prevalent in, and characteristic of, a warm to hot climate (mean annual temperature 16 - 20 degrees C) and a low but markedly seasonal rainfall (100 - 500 mm/annum) (Reeves, 1976).
2. Gypsum "desert rose" clusters and carbonate crusts similar to those of the Teekloof distal floodbasin facies are common in marginal playa-lake sediments today (Cody and Cody, 1988). Playas are a common feature of arid alluvial plains and form in topograpically low areas where the water table intersects the surface.
3. *Glossopteris* leaf impressions found on distal crevasse-splay surfaces of the Teekloof Formation all have small leaf areas compared to those of the Ecca Group. This may be interpreted as environmental dwarfism induced by xeric conditions (Eva Kovacs-Endrody pers. comm.). The presence of abcission layers at the *Glossopteris* leaf bases and pronounced growth-rings in the silicified wood (*Dadoxylon*), is an indication of strong climatic seasonality.

5.4.3. Palaeoclimatic Interpretion of the Vertebrate Fossils

The vertebrate skeletons were the largest sedimentary particles on the floodplains and, as such, they can give an indication of the hydrodynamics of the interchannel areas. The intensity and extent of bone weathering may be used as an indication of the duration of post-mortem pre-burial periods as well as the prevailing climatic conditions. From the taphonomic investigation it has been shown that -

1. The pattern of bone weathering in Teekloof therapsid fossils is similar to that observed in modern mammal bones on semi-arid alluvial plains such as the Ambesoli Park in Kenya (Behrensmeyer, 1978).
2. The high articulation ratios of some small therapsid herbivores with straight or reflexed spinal curvature is attributed to pre-burial mummification (Hill, 1979). This is the result of generally dry climatic conditions that rapidly desiccated the leathery skin before bacterial decomposition had time to reach an advanced state.
3. The occurrence of therapsid burrows in the Teekloof Formation is interpreted as behavioural adaptation by a partial homeotherm to combat relatively large diurnal temperature ranges. The mammal-like reptiles probably burrowed to near the water-table as a method of remaining cool during the day (aestivation). A fuller description of the burrow casts and a discussion of their palaeoenvironmental significance is included in the following section.

5.4.4. Palaeoclimatic Interpretation of Therapsid Burrows

Before this study, helical vertebrate burrows had not been reported from the Karoo or any of the Permian basins of the world, although straight inclined shafts with possible scratch marks had been described from the Lower Beaufort of the south-western Karoo (Turner, 1979), the middle Beaufort of the Eastern Cape (Da Silva, 1988) and the Upper Beaufort of the Orange Free State (Stanistreet and Turner, 1979). These were attributed to the digging activity of *Diictodon*, *Lystrosaurus* and *Procolophon* respectively.

Some reptile fossils from the Beaufort Group have modified forelimbs which are apparently adapted for digging. Cox (1972) described a small therapsid, *Kawingasaurus*, from the Lower Beaufort equivalent in the Karoo system of Tanzania which shows pronounced shortening and twisting of its humerus. Broadening of the digits on the manus of *Procolophon* is also interpreted as a digging adaptation (Colbert and Kitching, 1975).

Cistecephalus, a zone fossil of the Teekloof Formation, is very similar to *Kawingasaurus* and is described by Keyser (1973) as a "squirrel-like creature living in burrows and feeding on equisetalian fructifications". Cluver (1978) fully described the post-cranial skeleton of *Cistecephalus* and showed the anatomy of the forelimbs and pelvic girdle to be analogous to those of the Cape Golden mole and European mole. He concluded that *Cistecephalus* was at least semi-fossorial if not a full burrower.

No burrow casts have yet been found in the *Cistecephalus/Aulacephalodon* Assemblage Zone despite the abundant skeletal remains of an apparent burrowing animal. Preservation bias is often cited as the reason why the fossils of digging vertebrates and evidence of their burrows, are rarely found together (Voorhies, 1975). It is possible, however, that *Cistecephalus* did not maintain an open burrow system but rather backfilled or allowed its tunnels to collapse behind it. This would reduce the likelihood of a natural burrow cast forming.

The Beaufort burrows are similar in geometry to *Diamonelix*, large helical burrow casts from the Miocene rocks of Nebraska.

Diamonelix is interpreted as the dwelling structure of the primitive beaver *Palaeocastor* with the sub-horizontal terminal chambers having also served as breeding chambers (Martin and Bennet, 1977). If helical burrows were the normal dwelling or brood structures of *Diictodon*, they should be more abundant and have a longer stratigraphic range. It is possible that the Beaufort "diamonelices" were excavated in response to special environmental circumstances linked to climate (Voorhies, 1975). A modern day example of the influence of climate on the distribution, size and shape of reptile burrows is provided by the North American gopher turtle. This tortoise digs burrows only for hibernation and aestivation and prefers to terminate them in damp soil. In the arid south-western deserts individuals excavate shallow burrows about 1 m deep, but at the northern end of its range, they excavate communal living quarters which may exceed 10 m in length, yet under more equable climatic conditions, around Almos Sonora, they do not burrow at all (Auffenberg and Weaver, 1969). A similar climatic control could have determined the digging habits of dicynodonts and their hibernation and aestivation behaviour. *Diictodon* may have burrowed for the same reasons as the gopher turtle - to remain cool and moist under hot and dry atmospheric conditions. Spiralling may have been introduced to limit air circulation, allowing the humidity inside the terminal chamber to rise beyond that on the surface (Martin and Bennet, 1977).

It is perhaps significant that the stratigraphic distribution of vertebrate burrow casts known to date in the south-western Karoo is confined to the *Pristerognathus/Diictodon* and overlying *Tropidostoma/Endothiodon* Assemblage Zones. This is the interval in which the fossil assemblages undergo a major change as the large dinocephalians become extinct to be replaced by an assemblage of smaller forms such as *Endothiodon*, *Tropidostoma* and *Pristerodon*. It seems, therefore, that the smaller animals coped better with an environmental change of some sort. Burrowing was one of the ways in which the smaller animals coped with these changes and it appears to have been an adaptation to combat overheating. Thus indirectly, the behavioural adaptation of small herbivores is reflecting a basinwide change in climate toward more extreme temperatures both diurnally and seasonally.

Schultz (1942) on comparing the Miocene *Diamonelix* with some recent sciurid burrows, came to the conclusion that the tendency to dig helical burrows has developed independantly in unrelated lineages of rodents. The recent discovery of large helical burrow-casts in rocks of pre-mammalian age means that amongst the vertebrates, spiral burrowing can no longer be regarded as strictly mammalian behaviour. It has been shown that at least 50 million years before the first true mammals appeared, some of the therapsids, long regarded as the reptilian ancestors of mammals, were excavating spiral burrows and had perhaps become "behaviourally pre-adapted mammals". Even though dicynodonts have been identified as "diggers" they are generally regarded as an aberrant off-shoot of mammal-like reptiles, which were not directly involved in the mammal-like reptile/mammal transition.

5.5. PALAEOLANDSCAPE AND HABITATS

A recently published geological map of Gondwana (De Wit *et al.*, 1988) in its continental configuration of +/-150 Ma plots the southern Gondwanide orogenic belt, that formed the southern edge of the Karoo Basin at that time, some 2 000 km to the south of the position of the present day Nuweveld range. It is estimated that the width of the alluvial plain in the south-western portion of the Karoo basin during the accumulation of the Teekloof Formation was at least 1 000 km.

Calculations of average discharge (Q) based on meander wavelength and amplitude measurements are used to estimate the regional slope of the Teekloof alluvial plain by substituting Lane's (1937) equation (see Table 8). This gives a calculated slope of 0.00022 which is an extremely low gradient. However, the stream-length averaged gradient of the Ganges River, which falls a mere 100 m across the 500 km wide Indo Gangetic alluvial plain (Sehgal and Stoops, 1972), is equally shallow.

There is no evidence in the Teekloof succession for the presence of interfluve derived conglomerates such as occurs in the Lower Old Red Sandstone of Wales (Allen, 1979) nor have regional scale erosion surfaces been recognized such as those described by Kraus and Middelton (1987) from the Chinle Formation of Arizona. It appears that the drainage nets responsible for accumulating the Teekloof Formation were continuously aggradational, although on a local scale relatively sudden switches of channel courses (avulsions) caused numerous hiatuses in floodplain accretion. Although generally wetter, similarly evolving floodplains are described by Smith *et al.* (1989) in the Cumberland Marshes, Saskatchewan.

Figure 78 is an illustration of the interpreted palaeolandscape of the Teekloof Formation. The main geomorphic features are labelled and their sedimentary facies are represented according to their common stratigraphic relationships. Three large scale pedological columns are also represented showing the characteristics of channel bank, proximal floodplain and distal floodbasin palaeosols.

Thus the main topographic features of the Lower Beaufort alluvial plains were low (+/-10 m high) sinuous meanderbelt ridges at least 3 km wide that contained the main rivers. The only other positive relief would have been the convex crevasse- splay lobes supporting a network of ephemeral anastomosing channels.

Vegetation flourished on the moister areas of the floodplains. This is directly evidenced by the root moulds, leaf and stem impressions and rhiozocretions in the interchannel deposits.

Riparian or gallery vegetation flanking the drainage channels would have provided favourable habitats for most of the herbivorous therapsids (Fig. 78). The vegetation was perennial and flourishing as evidenced by the diversity and size of the therapsid herbivore populations and their attendant predators.

Through the process of cut-bank collapse, abundant fresh and partly humified plant matter was added to the channel bed along with soil and pedogenic carbonate glaebules. This was the main source of the organic matter that became incorporated into the lower point-bar facies and which later provided the optimal chemical environment for uranium precipitation.

The gallery-type vegetation flanking the Teekloof rivers provided habitats for larger dicynodonts such as *Endothiodon* who would have browsed on glossopterid trees and reed-like equisetalean plants. Smaller dicynodonts including *Diictodon* and *Oudenodon* would have fed on the understorey and groundcover of club-

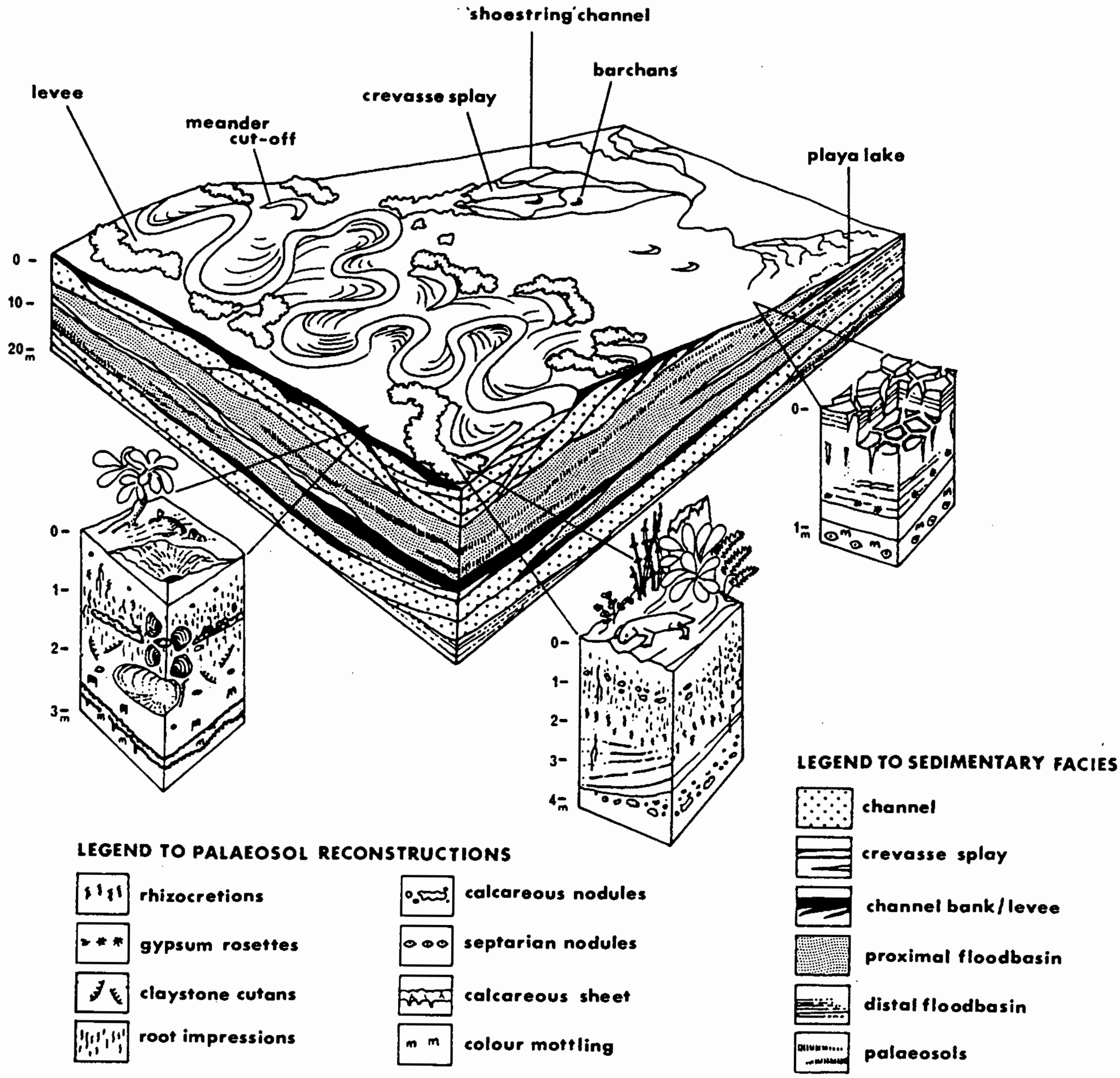


FIG. 78 Generalized palaeolandscape reconstruction and summary of the major sedimentary facies of the Teckloof Formation. The spacial distribution of channel and overbank depositional environments and their sedimentary facies are shown in the block diagram along with details of their palaeosol profiles and reconstructed habitats.

mosses and ferns. In the proximal floodplain areas at the foot of the meanderbelt slope, where the understorey thinned out, the smaller dicynodonts constructed underground burrows, some of which spiralled downwards into a terminal chamber (Fig. 78).

Further into the interchannel floodbasin, the vegetation became generally sparser with the result that more of the floodbasin alluvium was exposed. These areas were probably hostile to the therapsids for much of the year. Calcareous crusts, gypsum rosettes and siliceous glaebules with syneresis shrinkage cracks are indicative of a hydromorphic setting under evaporative conditions similar to a playa-lake.

Lack of vegetation and poorly developed soils combined with the threat of inundation and submergence during the wet season made the marginal playa areas generally inhospitable to vertebrates except perhaps for larger amphibians such as *Rhinesuchus* which are relatively better represented as fossils in these deposits than in other floodplain facies.

It is probable that windblown calcareous dust, picked up from the playa margins, was distributed over the entire floodplain providing a constant carbonate flux to the floodplain soils. In modern semi-arid alluvial plains aeolian dust has been shown to be the major source of calcium carbonate for caliche-bearing soils (Yaalon, 1964; Meyer *et al.*, 1988). This would explain how such widespread calcic palaeosols could have developed in a generally non-calcareous parent material. Aeolian re-working of the exposed bars on crevasse-splay sand sheets and the calcareous sand infill of distal floodbasin mudcracks supports this explanation.

6. CYCLIC SEDIMENTATION, STRATIGRAPHY AND PEDOFACIES SEQUENCES

6.1. STRATIGRAPHY AND CYCLICITY OF THE LOWER BEAUFORT

Beerbower (1964 p. 41) states that "cyclic sedimentation is natural to any alluvial plain and would be conspicuous by its absence". He describes the mechanisms involved in initiating and maintaining the repeated sequence of sediments known as cyclic sedimentation and groups them into two types namely, allocyclic and autocyclic mechanisms.

1. Allocyclic mechanisms - result from changes in supply of energy or materials to the system and include factors such as-
   (a) Eustatic change in sea level.
   (b) Climatic changes.
   (c) Irregular elevation of source area.
   (d) Spasmodic depression of depositional basin.
2. Autocyclic mechanisms - require no change in total energy and material input but involve the redistribution of these elements within the system. Mechanisms include the following-
   (a) Lateral migration of channels.
   (b) Avulsion of channels.
   (c) Crevassing and other overbank events.
   (d) Subsidence of depository by compaction or isostacy.

In the Lower Beaufort three magnitudes of cyclic expression or "orders" can be recognized. These are termed first to third in descending order of magnitude, after the notation adopted by McLean and Jerzykiewicz (1978).

6.1.1. First Order Cycles (Allocyclic/Autocyclic?)

These are large-scale cycles between 250 m and 2 500 m thick and delimit major, lithologically discrete sequences within the Lower Beaufort succession. The cycles are broadly upward-fining and are composed of a lower, erosively based predominantly sandstone sequence overlain and transitional with a predominantly mudrock sequence.

First order upward-fining cycles were first recorded in the Beaufort Group by Visser and Dukas (1979) in an area north of Graaff Reinet, where they were described as "megacycles". Stear (1981) recognized seven upward-fining first order cycles in the Lower Beaufort of the southwestern Karoo. Within the same succession, M.J. Jordaan (pers. comm.) recognizes only four.

Components of some of first order cycles within the Teekloof Formation of the Adelaide subgroup have been allocated an informal stratigraphic nomenclature applicable to the Beaufort West area (see Fig. 79). The Teekloof Formation is composed of two first order cycles, the lower made up of the arenaceous "Paalhuis member" (Turner, 1979) and the overlying argillaceous "Hoedemaker member" (Stear, 1980). The laterally continuous "Poortjie sandstone" (Roussouw and de Villiers, 1952) and the "Rietkuil sandstone" (Anderson and Fraenkel, 1979) occur near the base of the "Paalhuis member". The second first order cycle contains the arenaceous "Oukloof member" (Turner, 1979) at its base overlain by the "Steenkampsberg" argillaceous sequence (Stear, 1981).

Structural deformation of the Abrahamskraal Formation in the south-western Karoo hampers the accurate measurement of the stratigraphic succession. Stear (1981) delimits five repeated upward-fining sequences within the Abrahamskraal Formation. M.J. Jordaan (pers. comm.) believes this Formation to comprise a single first order cycle with a thickness up to 2 500 m.

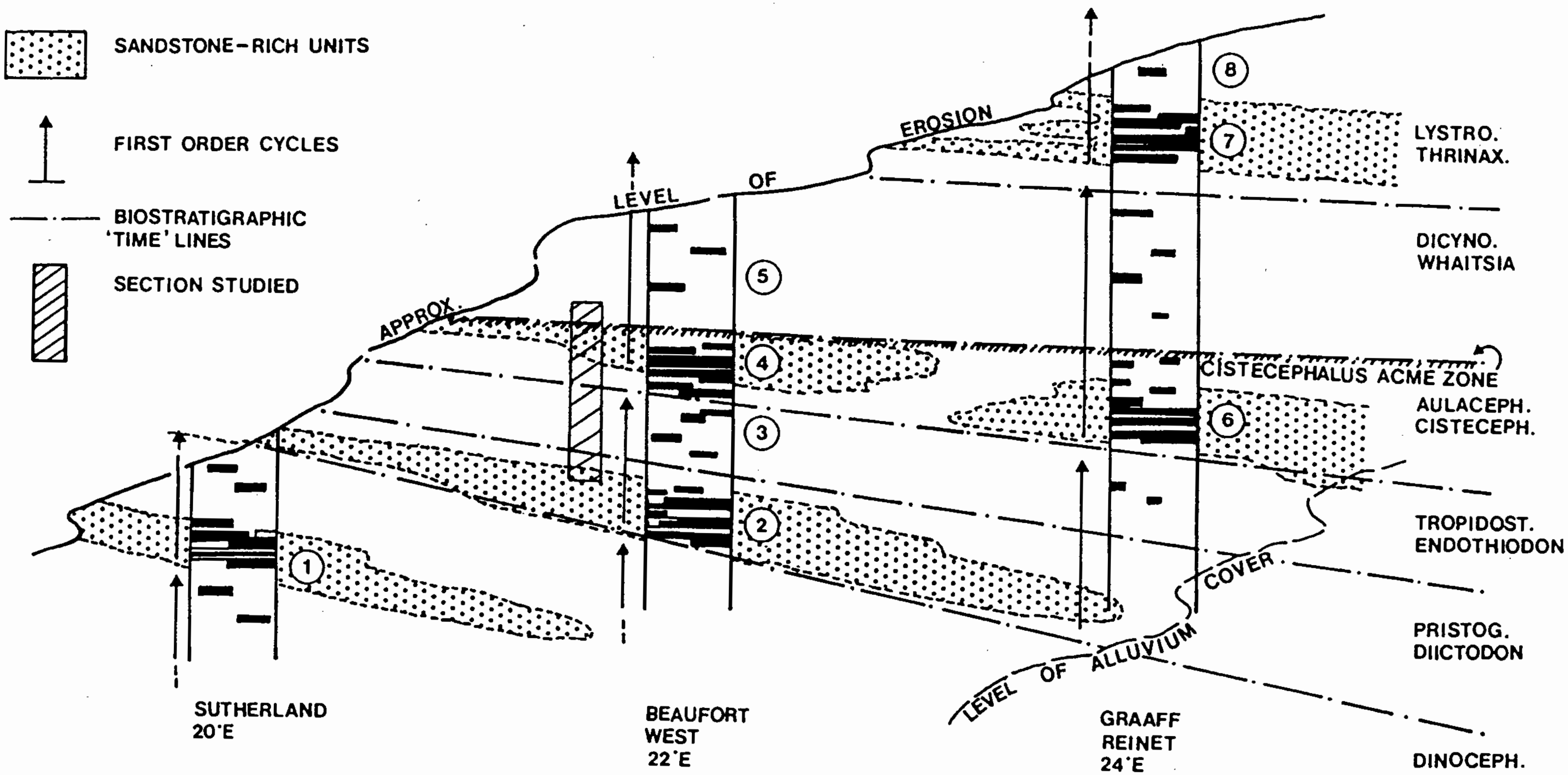


FIG. 79 Large scale fluvial architecture of the Teekloof Formation, west of 24 degrees E, showing the relationship between biozones and sandstone packages (which have been given an informal stratigraphic nomenclature) and the large scale first-order cyclicity. 1 = Verlatenkloof member, 2 = Poortjie sandstone member, 3 = Hoedemaker member, 4 = Oukloof member, 5 = Steenkampsberg member, 6 = Ouderberg sandstone member, 7 = Katberg sandstone Member, 8 = Burgersdorp Formation. The black horizontal bars are a schematic indication of channel sandstone density and connectedness.

An obvious, albeit broad correlation exists between the biostratigraphy of Keyser and Smith (1979) and the first order cyclicity recognized in the Lower Beaufort succession west of 24 degrees E (Fig. 79). The Dinocephalian Assemblage Zone coincides with the Abrahamskraal Formation. The *Pristerognathus/Diictodon* Assemblage Zone roughly correlates with the "Paalhuis member" and the *Tropidostoma/Endothiodon* Assemblage with the "Hoedemaker member". The "Oukloof" sandstones form the bulk of the *Cistecephalus/Aulacephalodon* Assemblage Zone and the "Steenkampsberg" mudrocks contain the *Dicynodon lacerticeps/Whaitsia* fauna.

The first order cycles of the Lower Beaufort succession in the south-western Karoo are broadly fining upward (thinning upward if referring only to the sandstone bodies) and reflect periods of disequilibrium between the alluvial plain morphology and total energy supply. The constancy of grain-size, texture and composition of the channel sandstones throughout the Lower Beaufort succession suggests that the complete succession was deposited in the distal portion of an aggrading alluvial system. The large scale cyclic variation is reflected in the ratio of sandstone to mudstone with no recognizable textural variation of the sandstone bodies either within a single cycle or between the cyclic sequences. The controlling mechanisms of such cyclicity probably worked through the total supply of energy to this part of the depository rather than through the supply of detrital material. The lower, predominantly sandstone portions of the first order cycles may have resulted from an extended period of channelization, accelerated channel migration and possibly lowering of sinuosity perhaps caused by a general increase in the volume or velocity of discharge. If tectonic activity in the source area is implicated as the controlling mechanism for the first order cyclicity (Visser and Dukas, 1979) there is a difficulty in increasing the energy input without a corresponding increase in maximum grain size. This is because any increase in gradient automatically initiates an erosive phase to re-establish grade.

The apparent discreteness of the "megacycles" without obvious basinwide lithological continuity also makes the purely tectonic control difficult to accept.

The Lower Beaufort depository was far removed from its source area so that any major source area uplift would be expected to have influenced a much larger section of the basin than appears in the stratigraphic record and there should be no difficulty in establishing lateral continuity of the "megacycles" between the southeastern (Visser and Dukas, 1979) and the south-western (Stear, 1981) parts of the basin. Visser and Dukas (1979) favour source area tectonism as the major control with the reasoning that the cycles are asymmetrical, ie. "fining upward", of varying thickness and that palaeocurrent measurements indicate differently located source areas. Walcott (1970) proposed a mechanism whereby loading brought about by tectonic thrusting in the source area causes isostatic subsidence which extends beyond the area of loading into the adjacent basin. This provides a "sediment trap" for the coarse clastics in the proximal areas. The distal areas are, therefore, only affected by an increase in discharge without increased sediment load. Such a mechanism could account for the first order cyclicity encountered in the Lower Beaufort but it would be expected to be more extensive affecting at least the southern half of the basin.

An alternative explanation for the first order cyclicity of the Lower Beaufort is that it reflects major natural shifts in the distributary system. This is supported by the following points -

(a) There are no major breaks in the succession which could be attributed to major changes in fluvial style. Both the lithostratigraphic and biostratigraphic records reflect an underlying stability of the depositional environment affected by relatively minor but repetitive changes in the intensity of channelization.

(b) Increases in channel intensity and rate of migration and possibly lowering of sinuosity without a corresponding increase in maximum grain size suggests that the dominantly sandstone units were the result of fluctuations in the total supply of energy regulated by the volume of discharge to certain parts of the basin. That these areas "shifted" rapidly from one part of the basin to another is also supported by the difficulty in basin wide correlation of stratigraphic units.

(c) Superimposing the biostratigraphic "time lines" onto the lithostratigraphic units of the Lower Beaufort in the southern Karoo basin highlights the fact that broadly speaking each biozone contains one of the stratigraphically significant predominantly sandstone units (Fig. 79). It is also notable that the biozones become gradually thinner in the direction of the arenaceous portion. Broadly speaking the *Tropidostoma/Endothiodon* Assemblage Zone comprises the westerly argillaceous "Hoedemaker member" and the easterly arenaceous "Oudeberg sandstone member" (Keyser, 1973) whereas the overlying *Cistecephalus/Aulacephalodon* Assemblage Zone comprises an easterly thick mudrock sequence which narrows down considerably westwards forming the arenaceous "Oukloof member". The western "Steenkampsberg" mudrocks give way to the arenaceous "Barberskrans member" (Johnson, 1976) in the east, both of which lie within the *Dicynodon lacerticeps/Whaitsia* Assemblage Zone.

It appears that the first order cyclicity recorded in the vertical succession in any one part of the southern Beaufort basin is made up of the proximal and distal equivalents of major locii of channelization. Such "shifts" in the locus of distal distributary systems on the featureless Lower Beaufort floodplain may have been caused by the increased alluviation of one site relative to adjacent areas causing the build up of a gradient between adjacent areas which became greater than the stream-length gradient of the channel system and, therefore, more favourable. Thus, by a combination of avulsion and river catchment the locus of channelization is dramatically "shifted" from one part of the basin to another. The problem remains, however, in accounting for the voluminous accumulations of predominantly mudrock sequences in a meandering fluvial system where overbank accretion rates are relatively slow. The major diversion of drainage nets from one part of the basin to another may be linked with this excessive alluviation of the "overbank" depository and could have been ultimately controlled by differential rates of subsidence between western and eastern portions of the southern Karoo Trough.

Allen (1978) predicted that decreasing the rate of basin subsidence would decrease the rate of floodplain accretion and cause increased reworking of floodplain deposits as channels migrate. This would be reflected in the stratigraphic record by an increase in the number and connectedness (Bridge and

Leeder, 1979) of multistoried channel sandstones as well as generally more mature palaeosols which would be truncated by the erosive bases of these sandstones (Allen, 1974a). This in effect describes the lower predominantly arenaceous portions of the Lower Beaufort first order cycles in which the multistoried Waterval sandstone occurs.

Increased rates of basinal subsidence would increase sediment accumulation rates on the floodplains whilst lowering the overall maturity of the palaeosols (Allen, 1978) and result in a sedimentary pile of predominantly overbank mudrocks with isolated single or weakly multistoried sand bodies. This describes the upper "predominantly argillaceous" portions of the Lower Beaufort megacycles in which the three dimensional Reiersvlei exposures are found.

Thus, the controls of first order cyclicity in the Lower Beaufort also determine the channel sandstone architecture and connectedness and are linked to differential rates of subsidence between adjacent areas of the basin. Although climate undoubtedly played an important role in determining the fluvial style (Turner, 1986), it is proposed that the subtle first order cyclicity of the Lower Beaufort is controlled by basinal subsidence through natural shifts in the drainage nets as a result of differential rates of aggradation and is, therefore, autocyclic.

6.1.2. Second Order Cycles (Autocyclic)

These cycles are defined by McLean and Jerzykiewics (1978) as -

> "intermediate scale cycles representing the record of the arrival of a river, its erosion into other floodplain sediments and its departure from that locality by lateral migration or abandonment followed by a period of only overbank sedimentation and terminated by the arrival of another river."

The second order cycles of the Lower Beaufort are interpreted as having formed in the above manner and have been termed "upward-fining" (Kubler, 1977;

Turner, 1978) in that above an erosive discontinuity fine-grained sandstone passes upward, often abruptly, into mudrock. By extending the facies analysis into the overbank deposits (as in the present study) it becomes possible to detect the more subtle "upward-fining" sequences recording an overall decrease in energy from channel to channel bank to proximal and distal floodbasin environments and the effect this had on soil formation. Most of the second order cycles of the Lower Beaufort are truncated to the extent that the "model sequence" derived by Kubler (1977) from Markov reduction is rarely observed in outcrop. Figure 80 records the second order cyclicity of measured sequences from the study area and illustrates the irregularity caused by the truncation of cyclic sequences. The truncation is attributed to two major factors. Firstly the fluvial system was subjected to an irregular pulsatory discharge regime encouraging the partial reworking of in-channel and channel-bank deposits. Secondly the high alluviation rates of the Lower Beaufort distributary system promoted regular abandonment of meanderbelts by avulsion allowing the sand bodies to become buried beneath floodbasin muds.

Second order cycles are the most easily recognizable in the field as they are usually small enough to appear in a single continuous exposure. Workers such as Allen (1965), Miall (1973) and Walker (1976) have analysed this cyclicity and reconstructed the hydrodynamic conditions responsible for its formation through comparison with studies of contemporary rivers. McLean and Jerzykiewics (1978) and Collinson (1978) point out the dangers of direct comparison of dynamic bedforms of modern rivers with the much compacted remnants preserved in the stratigraphic record. Cant (1976) noted that in the channel sands of a South Saskatchewan braided stream the large bedforms, formed during flood-stage, were selectively preserved compared to those formed during periods of normal flow. Studies of modern point-bar sediments by Jackson (1976) also highlight the disparity between the observed field relationships of sedimentary facies and that created by the "normalising" process of Markov chain analysis. He concluded that the preservation potential of the point-bar sediments was directly related to the migration behaviour of the meander, whereby migration by translation and rotation tend to destroy substantial amounts of the previously deposited

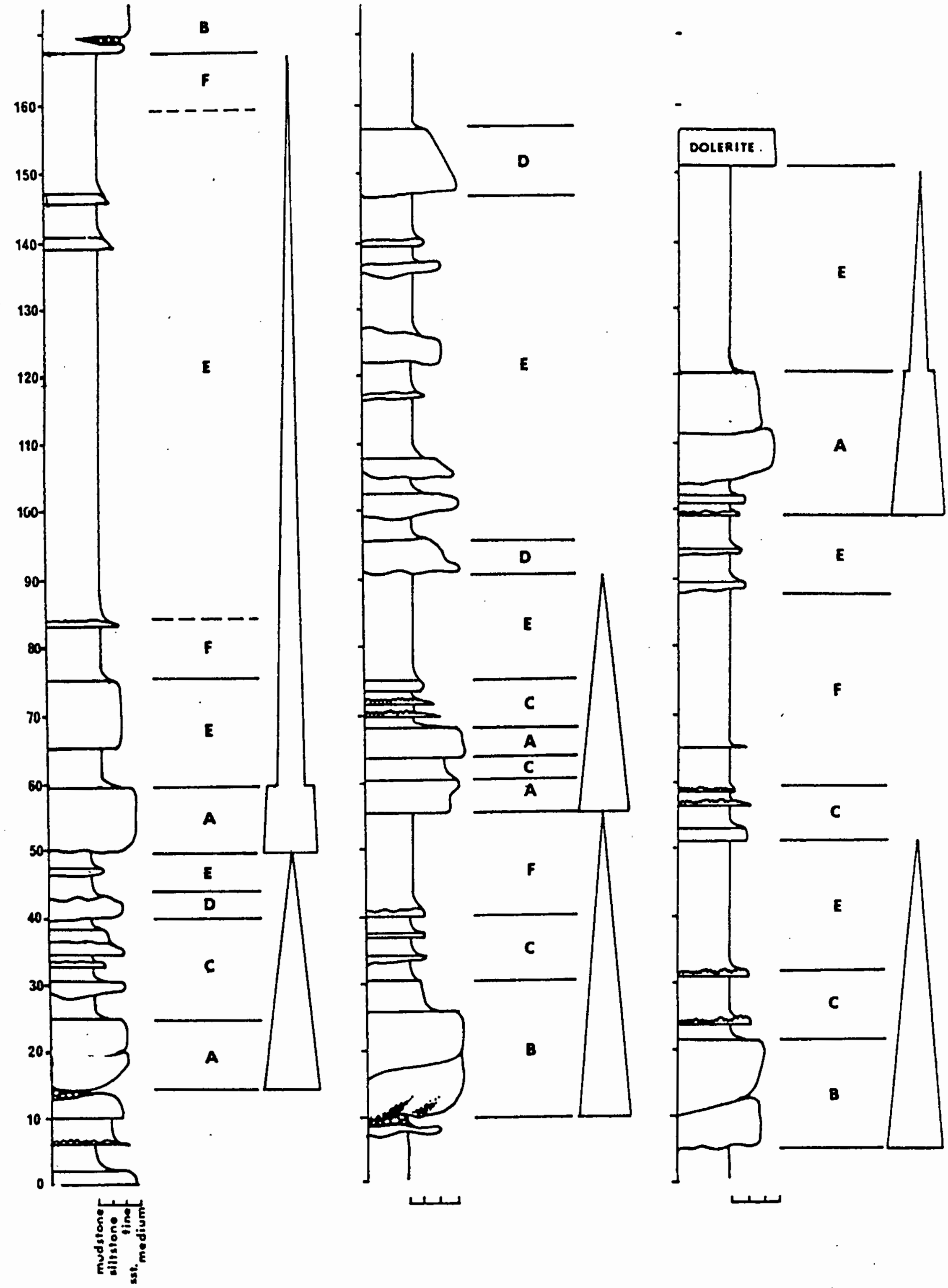


FIG. 80 Second-order fining-upward cycles recorded in the Teekloof succession in the Reiersvlei study block. A and B = Single and multistoried channel sandstone C = Channel bank/levee deposits, D = Crevasse-splay deposits, E = Proximal floodplain deposits, F = Distal floodbasin deposits. Scale in metres.

sediments. Migration by expansion would on the other hand, encourage the preservation of the complete point-bar sequence as in the case of the Reiersvlei meander.

6.1.3. Third Order Cycles (Autocyclic)

These are much smaller sequences (0.5 to 2 m), confined to the interchannel deposits, composed of vertical accretion deposits laid down during overbank events. They comprise a basal scoured surface overlain by either fine-grained ripple cross-laminated sandstone or siltstone followed by layers of mudrock of various colours. The mudrocks are compositionally a continuum between mudstone and siltstone and contain pedogenic nodules, root impressions and reptile skeletons. The thicker sandstone bodies (0.5 - 2 m) are interpreted as "splay" deposits and the thinner (less than 0.5 m) ones as being laid down on levees.

The controls of this sedimentation are wholly autocyclic, being a combination of uneven discharge, bank strength and channel sinuosity. The preservation potential of the Lower Beaufort interchannel deposits was apparently very high compared to modern distal fluvial systems. The ratio of sandstone to mudrock is never less than 1:2 and generally between 1:4 and 1:6. This reflects a high rate of distal alluviation only rarely observed in present day river systems such as the Indus, Mississippi, Hwang Ho and Ganges (Reineck and Singh, 1975).

6.2. PEDOFACIES SEQUENCES AND CYCLICITY

The three main types of Lower Beaufort palaeosols described in this study are interpreted as having formed on different parts of an aggrading floodbasin. It follows that a stacked sequence of palaeosols, without evidence of intervening erosion surfaces, may be regarded as having originally been in juxtaposition and are, therefore, representative of a "palaeocatena" (Atkinson, 1986) from elevated meanderbelt to lowland floodbasin. Bown and Kraus (1987) recognized that such sequences were not primarily controlled by differences in relief, although this certainly had an effect, but more importantly by the distance that the soil site is from the main channel. They proposed the term "pedofacies" as opposed to "palaeocatena" and defined it as "laterally contiguous bodies of sedimentary rock that differ in their contained laterally contiguous palaeosols as a result of their distance (during formation) from areas of relatively high sedimentation". This definition is acceptable for the Lower Beaufort palaeosol sequences with the qualification that a topographic effect caused by the gradient from areas of high to low sedimentation is more in evidence in the distal depression where hydromorphism dominates the solum.

Detailed sedimentological and pedological logs, of approximately 120 m of interchannel mudrocks, show commonly occurring sequences of pedofacies that are directly linked to the different scales of depositional cyclicity. Figure 81 illustrates some pedofacies sequences associated with second-order cycles in the study areas. The schematic and generalized second-order pedofacies sequence shown in Figure 82 begins in the channel-bank deposits immediately overlying a channel sandstone where one or two calcareous horizons with rhizocretions are developed. These give way upwards to the much more varied and distinctive nodular carbonate layers of the proximal floodbasin deposits with clay-enriched Bt- horizons. Interspersed between crevasse-splay sandstones, as many as ten palaeosol profiles may be stacked within the proximal floodbasin deposits. Not all contain slickensided textural B horizons and some are more hydromorphic than others, having fewer nodules and more pervasive colour mottling.

In the middle to upper parts of the interchannel sequence, thinly bedded shaley units contain septarian-type nodules and gypsum rosettes indicative of distal floodbasin deposits. They are usually terminated above by the scoured base of a crevasse-splay sandstone, or by levee-type deposits and only very rarely, by the erosive base of the succeeding channel sandstone. This forms a symmetrical upward sequence of progressively more mature palaeosols followed by more

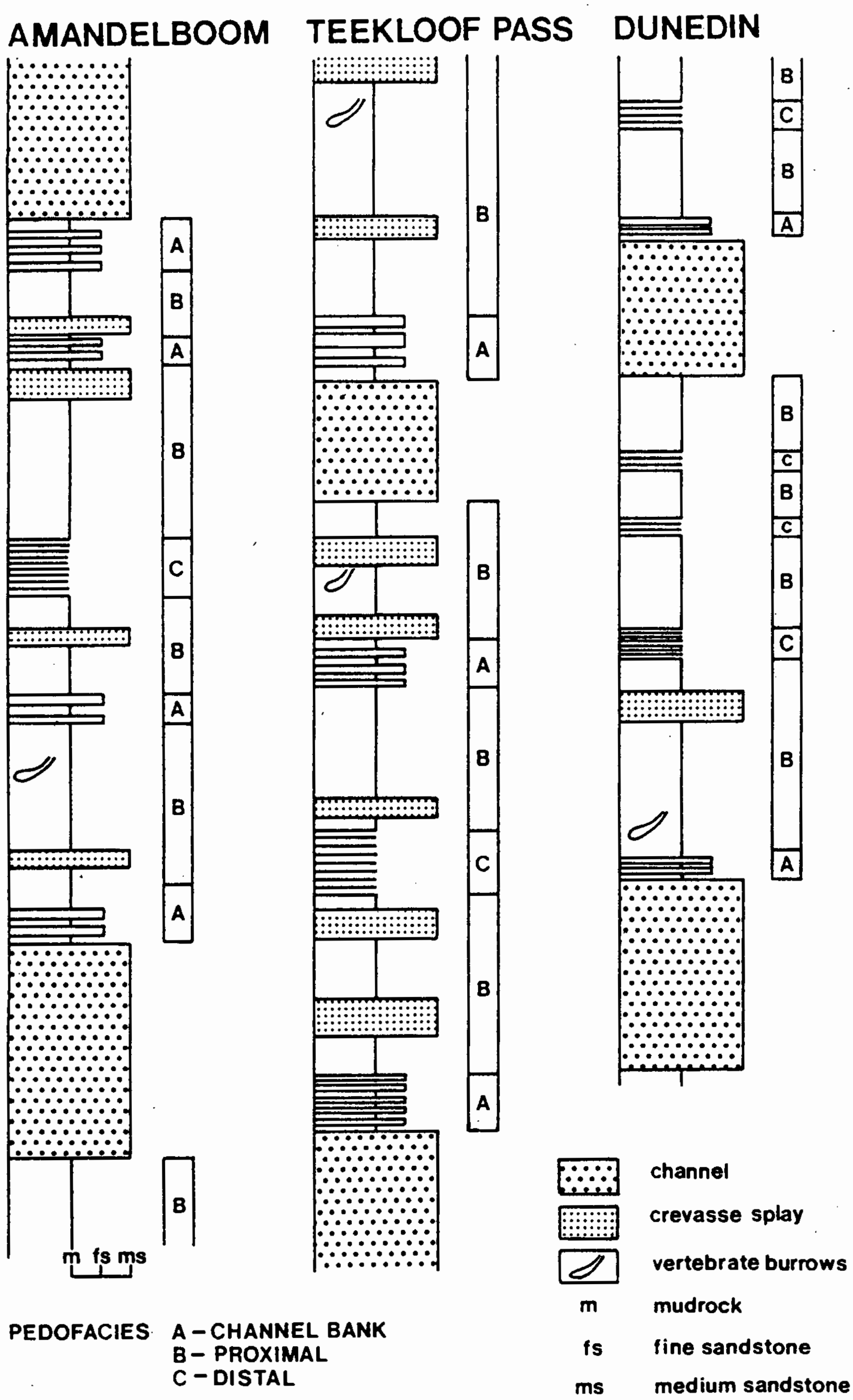


FIG. 81 Some pedofacies sequences recorded in measured sections of second order cycles at Amandelboom, Teekloof Pass and Dunedin localities. Note how the sequences tend to be symmetrical with the more mature palaeosols occurring toward the middle of the interchannel succession. Note too, the association of crevasse-splay sandstones with the proximal floodplain palaeosols and the preservation of vertebrate burrows.

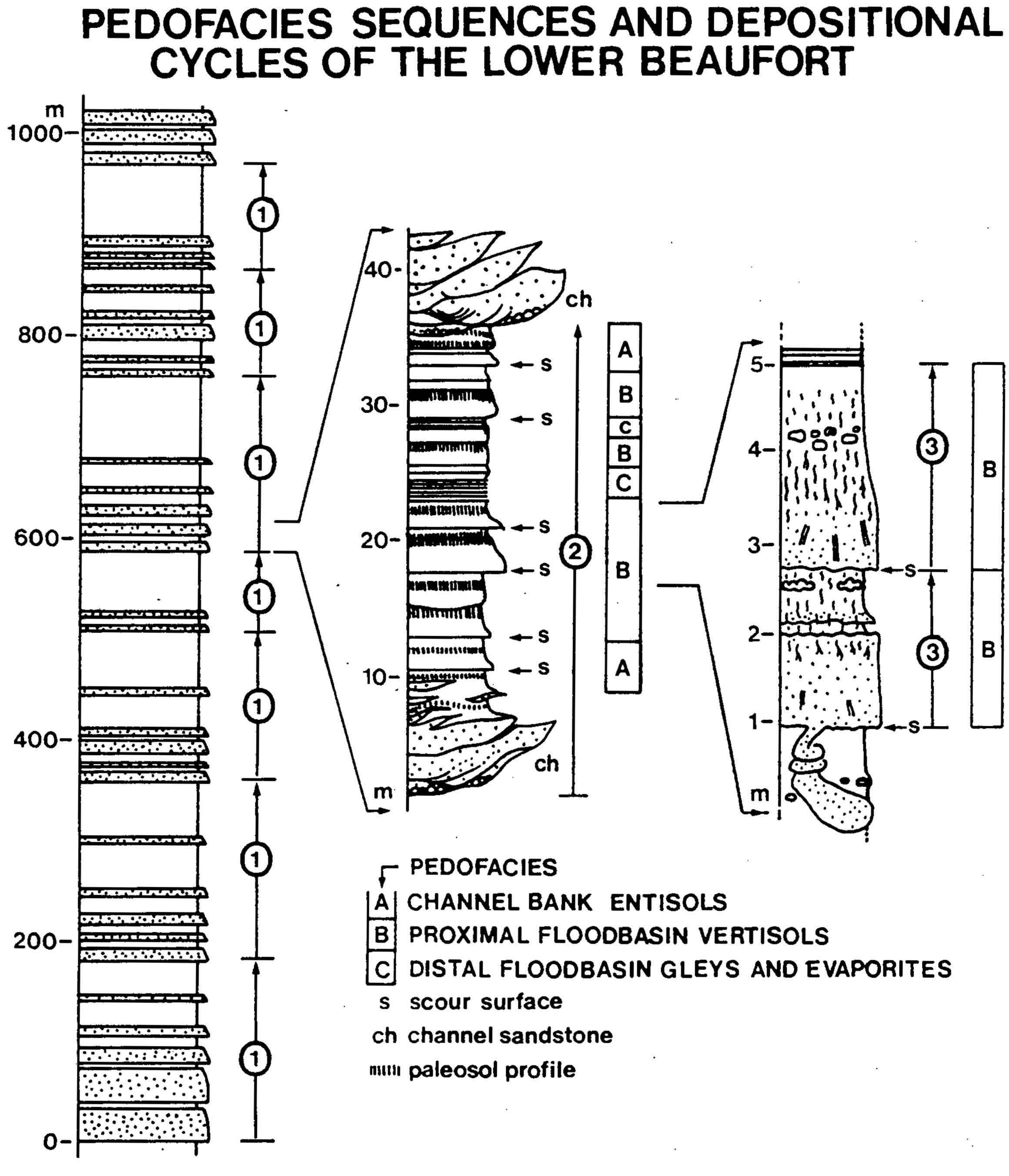


FIG. 82 Summary diagram showing the link between pedofacies sequences and depositional cycles in the Teekloof Formation of the Lower Beaufort. Circled numbers refer to the three orders of broadly fining-upward cycles recorded in the stratigraphic succession. Blocked letters refer to pedofacies and individual palaeosol profiles.

immature palaeosols punctuated by crevasse-splay deposits and terminated by channel deposits.

Sequences of stacked calcic palaeosols very similar to those of the Teekloof Formation occur in floodplain rocks of the Belly River Formation of Alberta (Jerzykiewicz and Sweet, 1988) and in the Willwood Formation, Wyoming (Kraus, 1987). It is proposed that the symmetrical maturation sequences of palaeosols in the Lower Beaufort second-order cycles are a consequence of a series of avulsions that initially removed the main channel further away from the site then subsequently brought it closer.

From measurements of the exhumed Reiersvlei sandstone, it was possible to reconstruct the palaeohydraulics, migration behaviour and abandonment of a major Teekloof river. Because channel avulsions were a common occurrence in these deposits (in the order of 1 every 1 500 years) and soil formation was controlled by proximity to these channels, such relatively sudden changes in the channel courses were recorded in the pedofacies sequences. Thus, repeated avulsions, moving the main channel further away from a soil site, would effectively lead to increasing pedogenic maturity followed by hydromorphic gleying. Conversely, avulsions, bringing channels closer to the soil sites, would result in progressively more immature pedofacies. This is the major autocyclic control of the second order pedofacies sequences.

There is preliminary evidence that suggests that the pedofacies sequences associated with the mudrocks of sandier members of the first-order megacycles, are generally more mature than those described in this paper (Stear, 1980). The mudrocks in the basal units do not contain the slickensided textural B horizons and the variety of glaebule morphologies found higher up the sequence. Neither do they exhibit the accretionary sheet type of palaeocalcrete that characterizes proximal floodplain palaeosols in the dominantly mudrock portion of the first-order cycle. In this respect, the Lower Beaufort first-order cycles may be similar to the first order pedofacies sequences described by Kraus (1987) in the Willwood Formation.

7. PALAEOENVIRONMENTAL SYNTHESIS AND SUMMARY

The major factors controlling the accumulation of Teekloof strata were the style and migration behaviour of rivers that transported and deposited the alluvial pile which is now preserved in the rock record. Close observation and analysis of these compacted and lithified sediments, as well as their contained fossils, has yielded details of the hydraulic conditions under which they were laid down and their post-depositional modification by atmospheric, pedological and biological agents. Following is a summary of this work presented in the form of a palaeoenvironmental synthesis of the Teekloof Formation.

The fluvial system responsible for depositing the Reiersvlei sandstone and associated strata is considered to be representative of the Teekloof fluvial regime. Figure 83 summarizes the reconstructed morphology and depositional environments of the "Reiersvlei meanderbelt". In itself, the extensive 3-dimensional sandstone outcrop records the arrival, migration, and abandonment of a large, Mississippi-sized meandering river that flowed in what is now north to north-easterly direction across an expansive, semi-arid, alluvial plain. The trunk rivers, of which there were several, were sourced in the subduction- related Gondwanide mountain chain some 1 500 km to the south and southwest. Unlike the Mississippi, however, the floodplains of these rivers were not swampy. They were submerged for the duration of major flood events but for most of the time, they were dusty, parched and sparsely vegetated.

Highly seasonal rainfall in the southern Karoo Basin and orographically induced downpours in the Cordilleran source areas resulted in an erratic discharge pattern of long periods of low-stage flow punctuated by catastrophic floods. Peak floods scoured the channel bed and point-bars and overtopped the channel banks whilst "dumping" abundant fines on the levee and proximal floodplain areas. During flood events discharge peaked at around 12 000 cubic metres per second with flow depths of up to 13 m over a bankfull width of some 350 m.

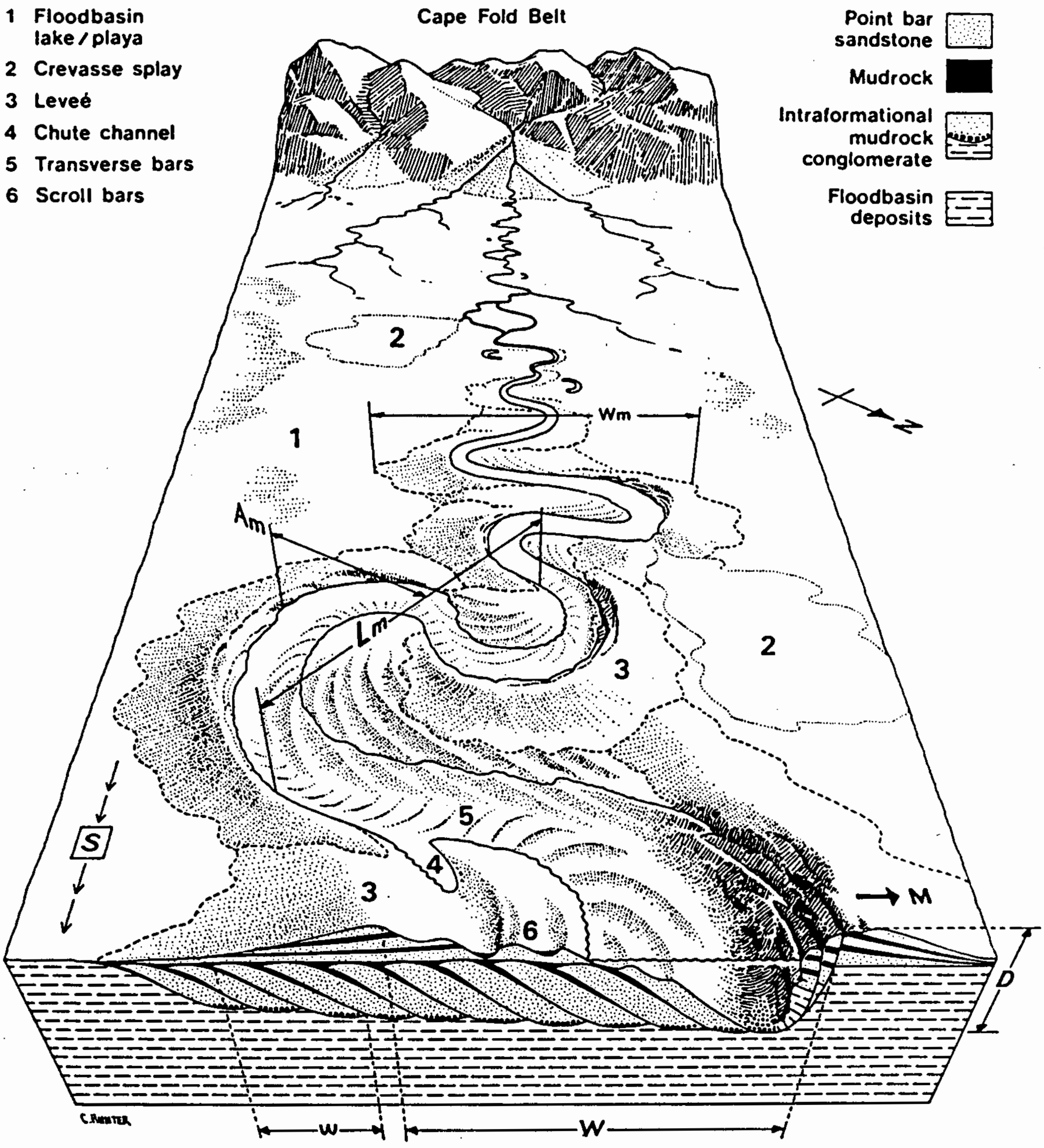


FIG. 83 Summary sketch of the morphology and depositional environments of the "Reiersvlei meanderbelt" during the Late Permian. The vertical scale in the cross-section is exaggerated at least 5 times. Refer to Tables 7 and 8 for quantitative estimates of meanderbelt width (Wm), meander wavelength (Lm) and amplitude (Am), bankfull channel width (W), point-bar width (w), bankfull depth (D), channel slope (S) and rate of meander migration (M).

Crevasse-splay fans were a common feature of the proximal floodplain areas. These were fan-shaped sand sheets that emanated from points where narrow channels had breached the channel banks, allowing floodwaters to spill out away from the meanderbelt rise, across the flanking floodplain. Breaching of the channel banks was most prevalent on the outside of the apices of tight meander loops. The adjoining floodplain areas were thus occupied by several "generations" of crevasse-splay progradation. This is reflected in the lithology and sedimentary sequences of the proximal floodplain facies.

Flow along the system of branching shallow channels on the splay sand sheets was essentially "flashy" and ephemeral. Between flood events these channels dried up and aeolian reworking of exposed sandy "interfluves" was common. Successive floods usually re-occupied the crevasse-splay channel network causing multiple re-working, super-position and progradation of sand lobes further into the floodbasin. Some of the larger splay complexes toed into floodbasin lakes that temporarily occupied the axial regions between meanderbelts.

The competence of these overbank floods is evidenced by the high disarticulation ratios of vertebrate skeletons that were rolled-over, entrained, transported, sorted and embedded by these flows. Some fully articulated and some disarticulated but fully associated skeletons were trapped inside underground burrows, either alive or already dead, singly or in groups, and became entombed by sheet flood deposits.

Rapid deceleration and shallowing of flow during waning flood contributed to the preservation of upper flow-regime structures in channel-bed and point-bar deposits. Further lowering of water levels, as the thalweg returned to normal flow path, resulted in shallow ponds and lakes of standing water in depressions on the point-bars, crevasse channels and over most of the axial (distal) floodbasin areas. This is where most of the muddy sediments were allowed to accumulate leading to the preservation of sandstone palaeosurfaces that display suites of sedimentary structures and trace fossils characterizing each of these three environments.

In the proximal floodplain areas between crevasse-splay sand sheets, narrow, straight to slightly sinuous distributary channels carried floodwaters away from the more mature crevasse-splays toward the distal floodbasin areas, eventually issuing into the axial floodbasin lake. The larger lakes were probably permanent although the semi-arid climate and seasonal flooding caused large fluctuations in volume, temperature and salinity of the lake waters. Their shorelines seasonally migrated over considerable distances imparting an alternating evaporitic/hydromorphic overprint on the marginal lacustrine sediments, simulating playa-lake conditions.

Riparian-type vegetation flourished on the banks of the trunk rivers and along watercourses crossing the crevasse-splays and proximal floodplains. It was dominated by broad-leaved deciduous *Glossopteris* trees and reed-like equisetalean horsetails. An understorey of small ferns and club-mosses provided a major food source for the diversity of small herbivorous therapsids of which *Diictodon* was the most common. The number and diversity of vertebrate fossils shows that they were members of non-migratory populations living in ecologically stable communities on the banks and floodplains of the Teekloof rivers. The communities comprised a high percentage of herbivores, outnumbering the carnivores by about 60:1 and each species, of which there were many, was well adapted to its particular niche.

To support the ecologically stable therapsid populations, vegetation must have been much more plentiful than the fossil record indicates. This is confirmed by the abundance and maturity of palaeosols in the stratigraphic succession. The palaeosols contain root channels, root casts and rhizocretions that attest to the former presence of dense plant growth. They also contain abundant palaeo-caliche and some vertisol textures that are similar to those of modern soils on the semi-arid Indo-Gangetic alluvial plain.

Comparison of the morphology and petrology of palaeo-calcrete glaebules in Teekloof floodplain rocks with subrecent calcretes suggests that the former were formed under a semi-arid climate of long warm to hot summers and short wet winters with mean annual temperatures of around 16 to 20 degrees C, possibly rising to 25 degress C, and a mean annual rainfall of 500 to 800 mm.

Pedogenesis, skeletal disarticulation and bone weathering are time dependant processes and all three may be arrested by rapid burial beneath flood deposits. In the Teekloof Formation both the bones and the soils had a high preservation potential and are commonly fossilized. They may be analysed in outcrop to provide some time constraints on the periodicity of flooding and overall accretion rates. As an illustration, palaeosols are used to determine the time taken to accumulate a 45 m rock succession on the farm Leeukloof in the Reiersvlei study area. It is calculated that a total of only 212 000 years was needed to actually deposit the alluvium. However, between depositional events, long periods of essentially non-deposition allowed soils to develop and mature.

By calculating the minimum time needed to form the 17 mature soil profiles in the succession it is estimated they represent some 238 000 years of non-deposition. Thus, although sedimentation rates of individual beds was quite high, resulting in the rapid burial and vertical "stacking" of palaeosols, the extended periods between flood events accounted for more than the time spent in accumulating the alluvium. A calculated and compaction- adjusted average sedimentation rate for this interval is 0.28 mm/year. This rate drops when the non-deposition periods are included to give an average floodplain accretion rate of 0.13 mm/year.

Well-vegetated and pedogenically cemented alluvium provided considerable bank strength to the major rivers and their tributaries, but they were susceptible to undercutting and collapse during rising floods. Such cut-bank collapse caused sudden shifts in the thalweg, resulting in irregular inner-bank accretion and a "jerky" expansion of meander loops. Erosion of the slumped bank material released abundant fresh and partially humified plant material into suspension, leaving a residual lag of cohesive mud pebbles and calcareous glaebules.

Over a period of some 1 500 - 2 000 years the Reiersvlei meanders continued to expand and increase in curvature at a rate of 0.6 to 0.885 m/year. Incipient chute cut-offs developed which would eventually have been completed had not an upstream crevasse channel captured the thalweg and gradually diverted the river into an adjacent floodbasin.

Following avulsion and subsequent abandonment of the downstream "Reiersvlei meanders", overbank sedimentation slowly buried the crescentic point-bars and infilled the channel with vertically accreted sand/silt flood couplets.

The number of major rivers that drained into the E-W trending southern Karoo trough varied both regionally and through time. These variations are a reflection of disequilibrium between the alluvial plain morphology and the total supply of energy leading to channel-rich and channel-poor deposits that, when superimposed, are reflected in the stratigraphic column as large scale first-order fining-upward depositional cycles. Such cycles, two of which make up the Teekloof Formation in the study block, are traditionally attributed to tectonic pulses in the source area. However, in this case, it is proposed that differential rates of basinal subsidence between the western and eastern regions of the southern Karoo Basin caused major "shifts" in the drainage nets flowing off the southern mountains. These "shifts" were in response to excessive alluviation in the region of greater basinal subsidence which eventually resulted in steeper surface gradients between adjacent regions on the alluvial plain than in the downstream direction. Once the drainage net had switched to a more stable part of the basin, it dissipated its energy by multiple reworking of its floodplain deposits with the result that channel deposits became volumetrically more abundant in the alluvium and the degree of connectedness of channel deposits increased to the extent that multistoried and multilateral sand bodies accumulated.

Thus, the controls of first-order cyclicity in the Lower Beaufort also determine the channel sandstone architecture and connectedness and are linked to differential rates of subsidence between adjacent regions of the basin. Although climate undoubtedly played an important role in determining the fluvial style it is proposed that the subtle first order cyclicity is a reflection of natural shifts in drainage nets that were not controlled from outside the depository and are, therefore, autocyclic.

The recognition of sub-environments within the interchannel facies association of the Lower Beaufort may not be of immediate interest to the exploration geologists as these rocks have not, as yet, yielded any significant concentrations of uranium mineralization. However, this study has shown that the interchannel facies, especially the levee deposits, are closely associated with the channel sandstones. Studies of the controls of uranium localization in the Lower Beaufort sandstones in the southwestern Karoo (Moon, 1974; Kubler, 1977; Le Roux *et al.*, 1979; Le Roux and Teons, 1986; Cole and Lubschangne 1985; Turner, 1985) all agree on the significant association of uranium ores with coalified plant remains. They disagree, however, on the closeness of the association and the processes inferred from such a coupling. Because plant remains have a major control over the accumulation of sandstone-hosted uranium ores in the Lower Beaufort, an understanding of the origin and distribution of such material within the channel deposits may be of importance.

The common uranium minerals of the southwestern Karoo are coffinite and uraninite. These are oxidized in outcrop to secondary uranium-bearing minerals such as metatorbanite, uranospinite and uranophane. Molybdenum is often associated with the uranium mineralization (Eddington and Harrison, 1979) but the peak concentrations are spacially separated (Anderson and Fraenkel, 1979; Cole, 1986). In study area two, secondary uranium minerals are visible on partings of horizontally laminated, poorly sorted, medium-grained sandstone and within the intraformational pebble conglomerates in the basal parts of single-and multistoried channel sandstones. This type of secondary mineralization is derived from the oxidation of high sulphide, low carbonate ore (Jakob, 1979). A second type of mineralization is also evident in the point-bar sub-facies of some channel sandstones as highly resistant pods of brown weathering massive calcareous sandstone known locally as "Koffieklip". This is the weathered expression of a carbonate-rich uranium ore (Jakob, 1979).

It has been established that the channel-bank levee sediments supported well-developed perennial vegetation and that, in the Teekloof Formation, the rivers were of medium to high sinuosity with a "flashy" discharge. Under such conditions, undercutting and collapse of concave banks would have regularly contributed considerable amounts of both living and partly humified plant material to the thalweg scour pool. The two types of vegetable matter would have had different hydrodynamic properties, the former tending to float and the latter being transported as bedload along with other clasts derived from the slumped banks such as clay clods, indurated silts, pedogenic glaebules and reworked vertebrate bones.

In the Teekloof channels, most of the lag conglomerate accumulated in the thalweg scour trough but some was transported during peak floods into depressions on the upstream side of the point-bars. The fresh, non-humified, floating vegetation was probably stranded on the upper point-bar especially in swales and in crevasse channels. At low water stage all but the lowermost parts of the point-bar drained allowing decompsition and oxidation of much of the exposed plant trash. Following avulsion and abandonment of the main channel, the point-bars would have become heavily vegetated promoting pedogenesis and, as in other parts of the floodplain, the downward translocation of carbonate. It is possible that the carbonate-rich pods in the middle and upper point-bar facies are simply lateral equivalents of palaeo-calcretes in the levee and proximal floodplain facies. The association of "Koffieklip" with organic matter supports this interpretation.

Thus the amount and distribution of organic matter in the channel sandstones is determined by the hydrology and migration behaviour of the river. The distribution and concentration of uranium in the channel sandstones of the Teekloof Formation matches that of organic matter and appears to be controlled, in part, by the preservation of large amounts of organic-rich collapsed cut-bank material within the more porous channel-bed sands.

This study has demonstrated the advantages of an interdisciplinary approach to field geology mainly in increasing the detail and the depth of the interpreted information. Research aimed at a greater understanding of modern taphonomic processes should greatly enhance the interpretation of the fossil record. In this respect, more qualitative research needs to be done on the hydraulic behaviour of *Diictodon* skeletons in various stages of disarticulation under non-channelized suspended-sediment-rich sheet flows.

An interesting follow-up to this study is to compare and contrast the fluvial facies, vertebrate taphonomy and palaeosols of the Teekloof Formation with those of the Elliot Formation at the top of the Karoo Sequence and with time equivalent successions from other parts of southwestern Gondwana, eg. Antarctica, India and Zambia. Combining this study with an analysis of the tectonic evolution of southern Gondwana should reveal more accurate methods of correlation between the sequences and may highlight major depositional cycles that are linked to datable orogenic events.

8. ACKNOWLEDGEMENTS

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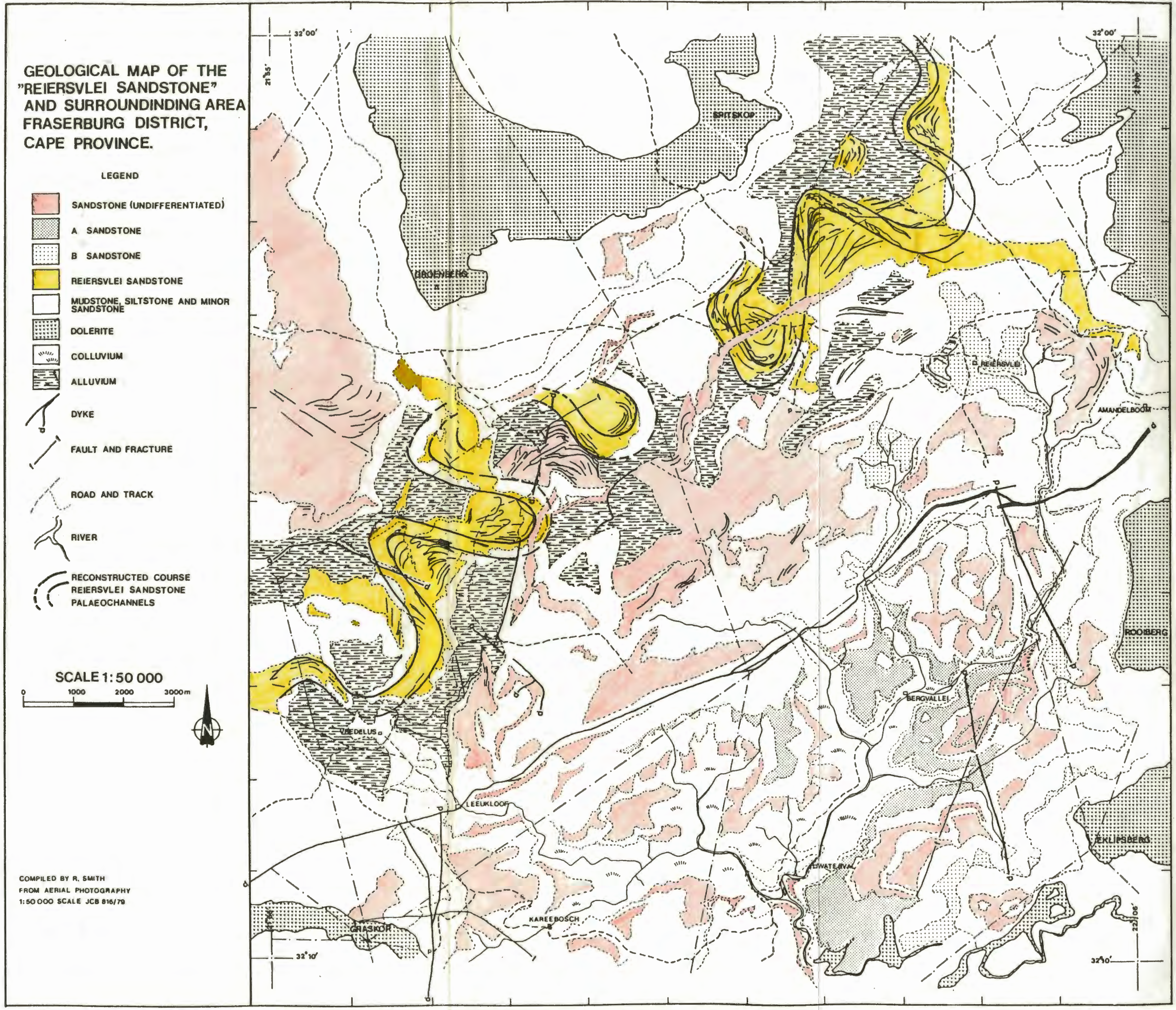
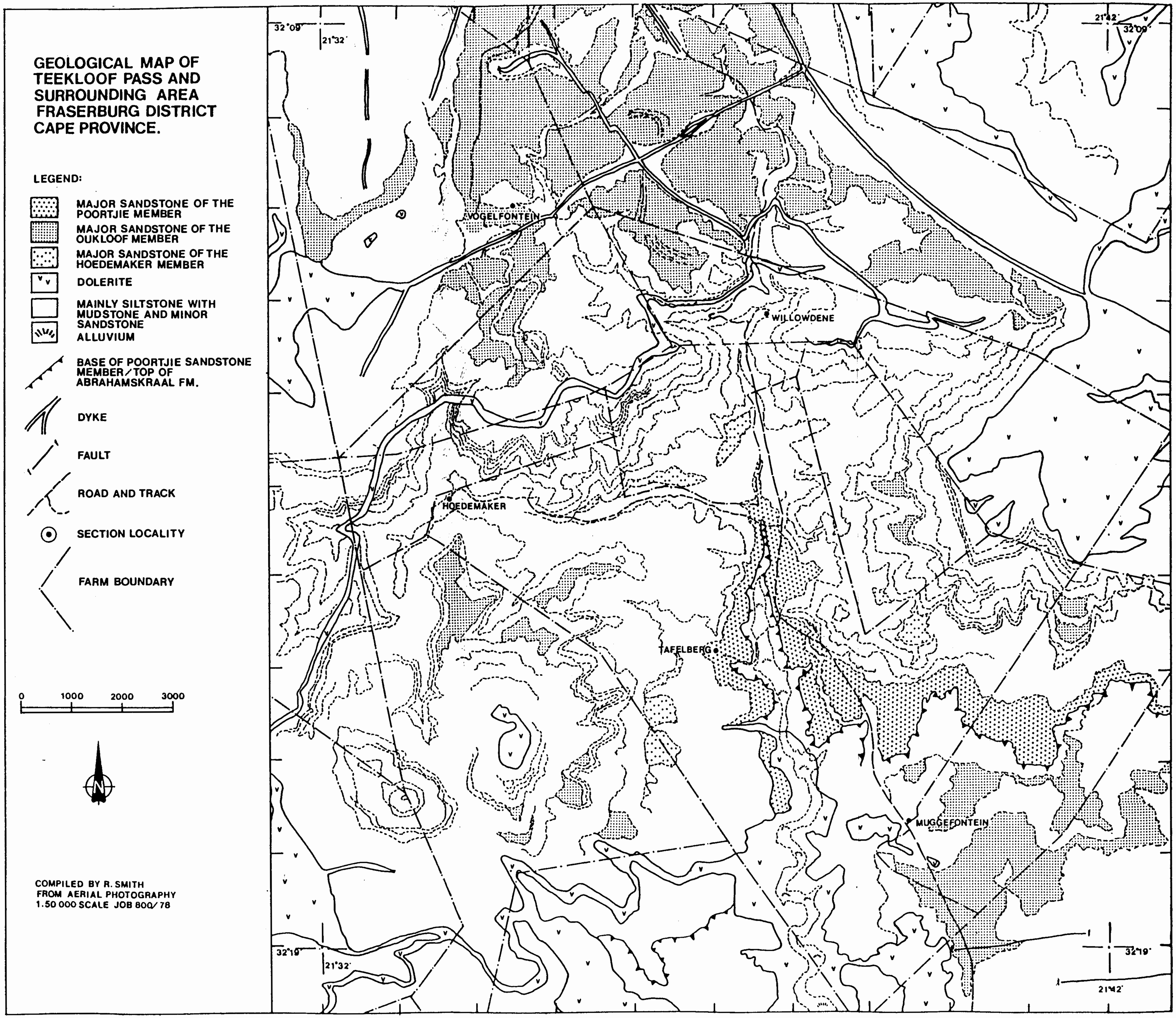
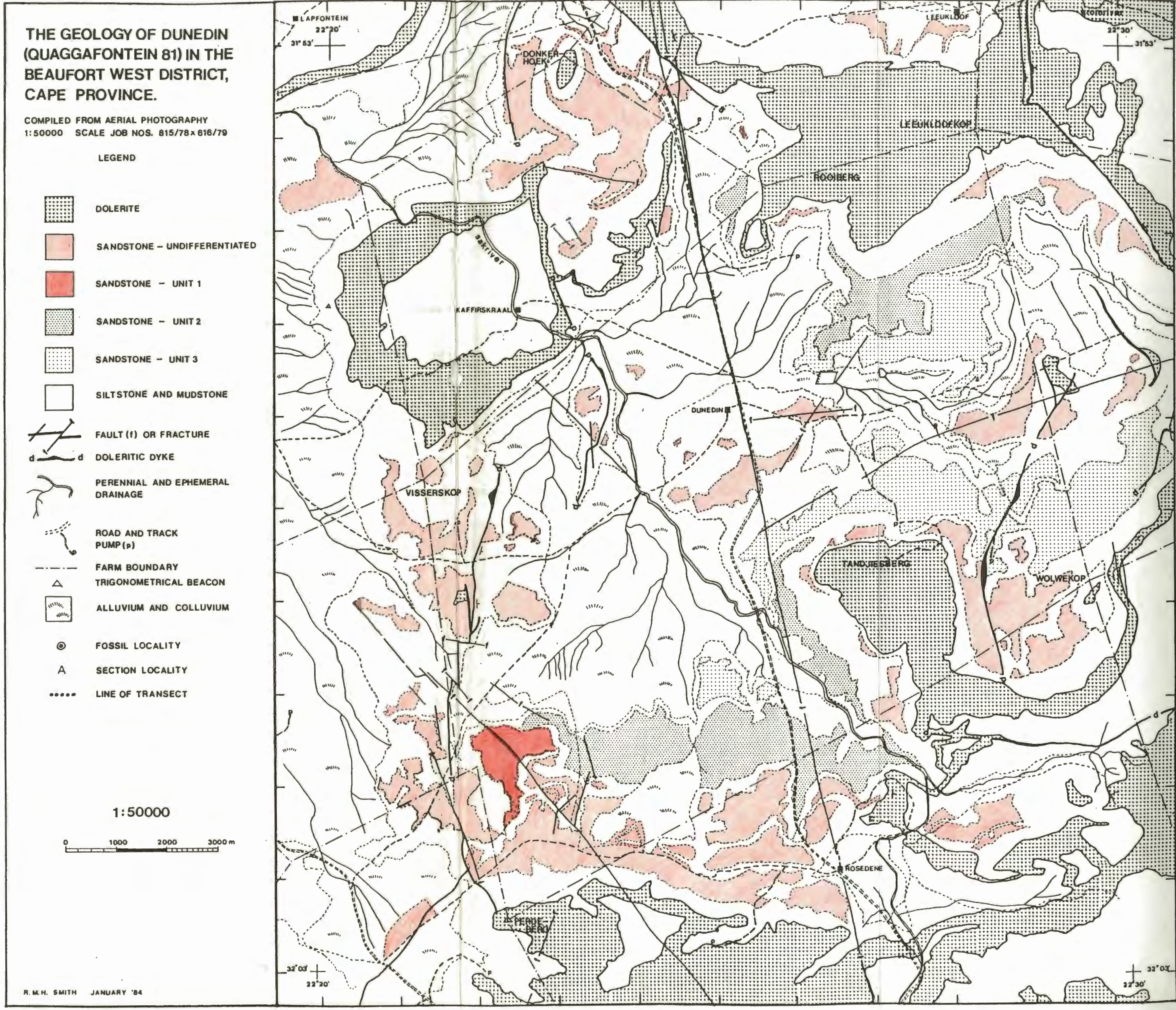


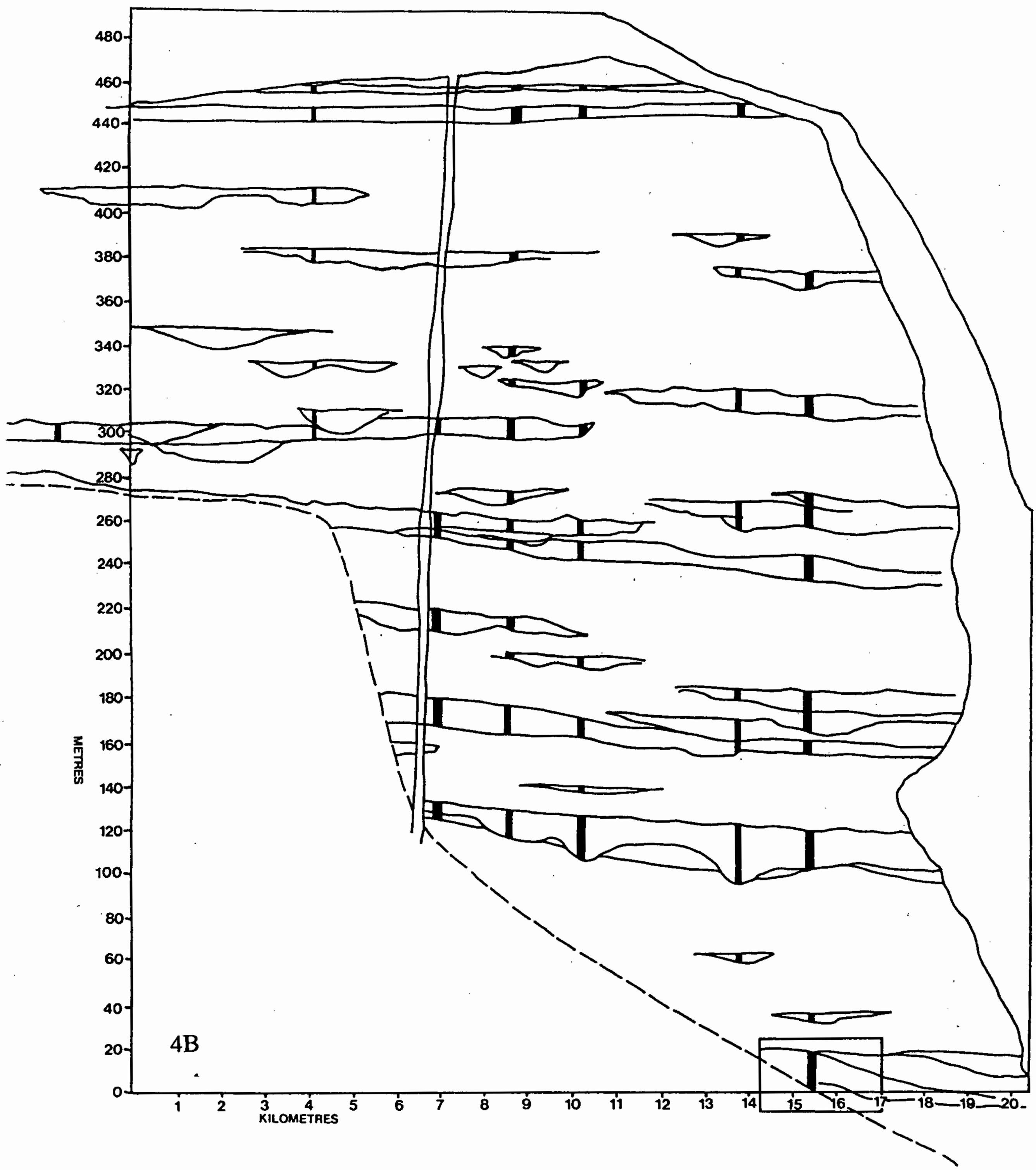
APP. FIG. 1 Geological map of study area 2 (see Fig. 1) including the "Reiersvlei Sandstone" and surrounding area, Fraserburg district, Cape Province.



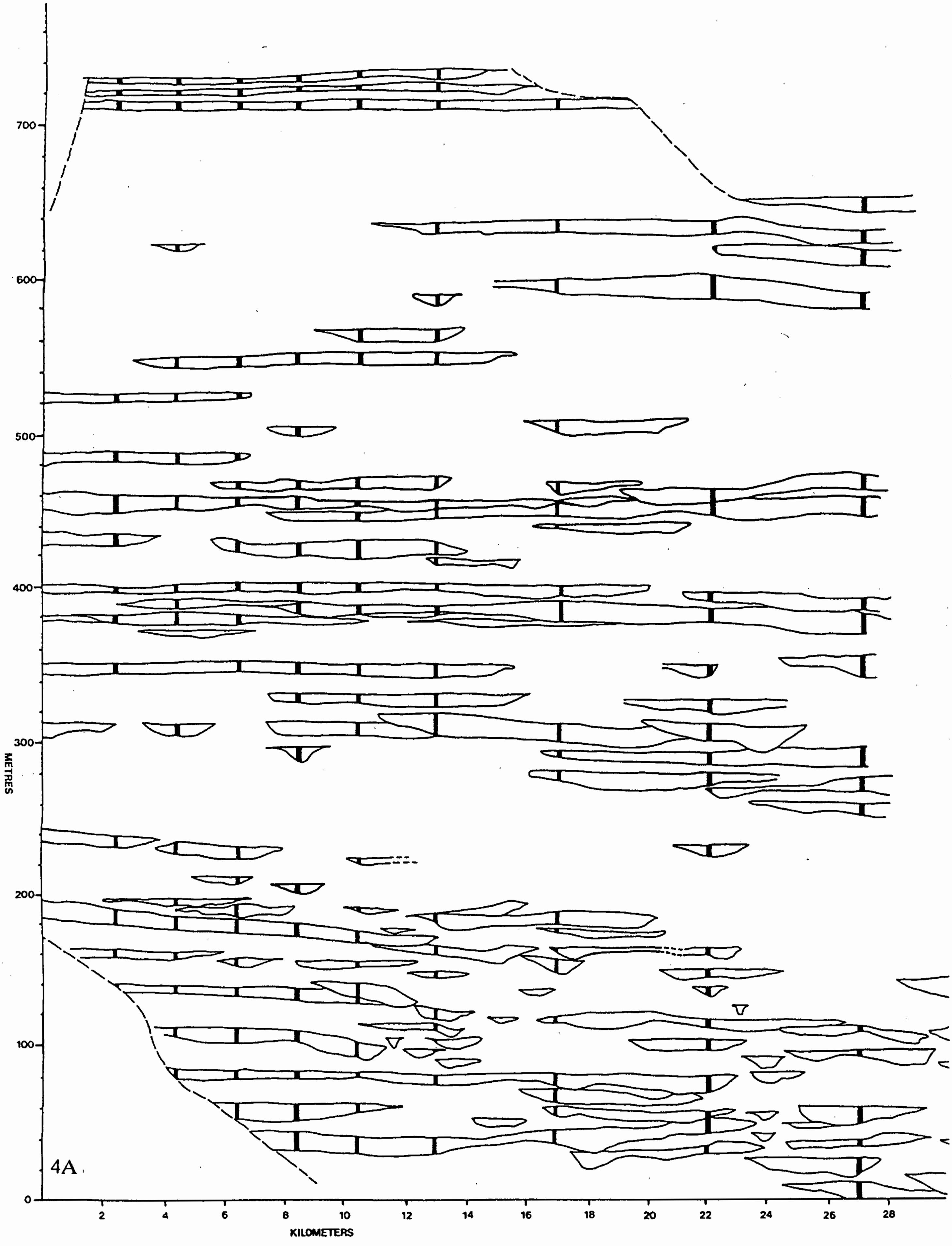
APP. FIG. 2 Geological map of study area 1 (see Fig. 1) including Teekloof Pass and surrounding area, Fraserburg district, Cape Province.



APP. FIG. 3 Geological map of study area 3 (see Fig. 1) covering the area around Dunedin (Quaggafontein 81) in the Beaufort West district, Cape Province.



APP. FIGS. 4A & 4B Macrostratigraphic panel sections of Teekloof Formation strata exposed in the Nuweveld Escarpment. See figure 6 for location of sections. Note that the vertical exaggeration is 50 times. Solid bars indicate approximate position of transect. The block outlined on the lower edge of section 4B is the Waterval Sandstone of App. Figs. 5A - C.



METRES
700
600
500
400
300
200
100
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
KILOMETERS
4A

APP. FIGS. 5A TO 5C Longitudinal cliff-sections and columnar logs of the Waterval multistoried channel sandstone. Note the vertical exaggeration of 2 on the cliff sections and 5 on the columnar logs.

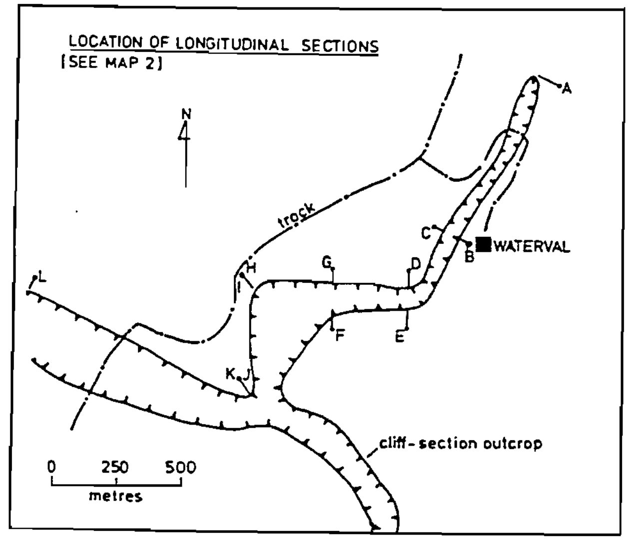
APP. FIG.5a

LONGITUDINAL AND COLUMNAR SECTIONS SHOWING SEDIMENTARY STRUCTURES OF A CLIFF EXPOSURE ON THE FARM WATERVAL: SECTION ABCD

APP. FIG.5b

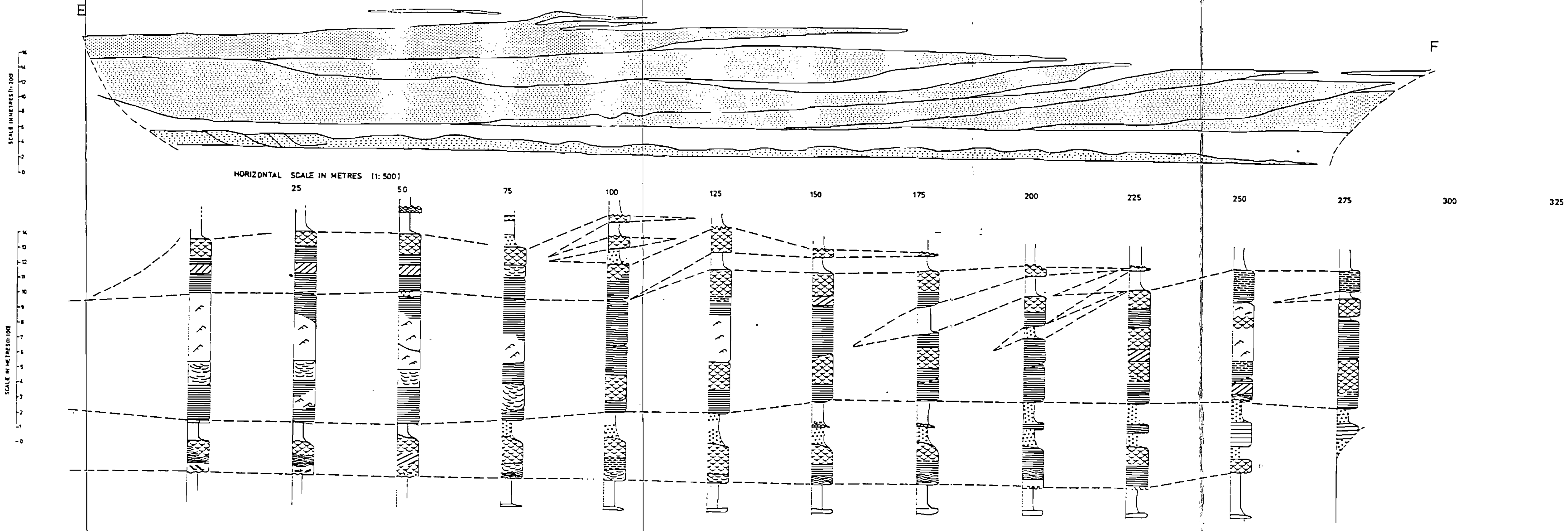
LEGEND TO LONGITUDINAL SECTIONS

- SANDSTONE UNIT I
- SANDSTONE UNIT II
- SANDSTONE UNIT III
- EROSION AND REACTIVATION SURFACES



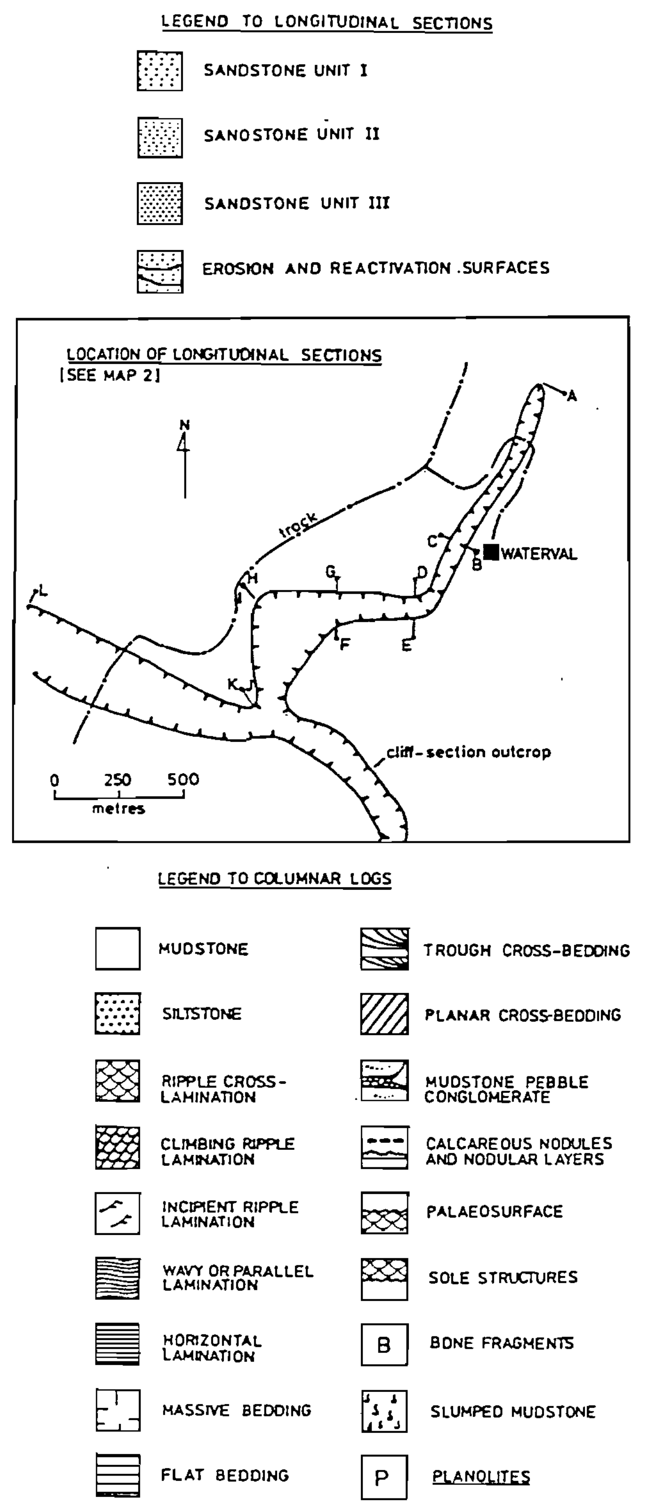
LEGEND TO COLUMNAR LOGS

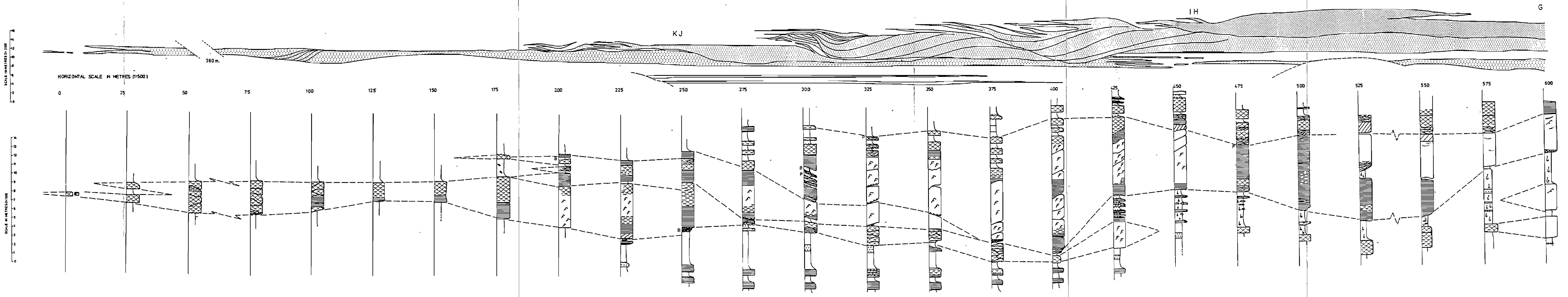
- MUDSTONE
- SILTSTONE
- RIPPLE CROSS-LAMINATION
- CLIMBING RIPPLE LAMINATION
- INCIPIENT RIPPLE LAMINATION
- WAVY OR PARALLEL LAMINATION
- HORIZONTAL LAMINATION
- MASSIVE BEDDING
- FLAT BEDDING
- TROUGH CROSS-BEDDING
- PLANAR CROSS-BEDDING
- MUDSTONE PEBBLE CONGLOMERATE
- CALCAREOUS NODULES AND NODULAR LAYERS
- PALAEOSURFACE
- SOLE STRUCTURES
- B BONE FRAGMENTS
- SLUMPED MUDSTONE
- P PLANOLITES



LONGITUDINAL AND COLUMNAR SECTIONS SHOWING SEDIMENTARY STRUCTURES OF A CLIFF SECTION ON THE FARM WATERVAL : SECTION E–F

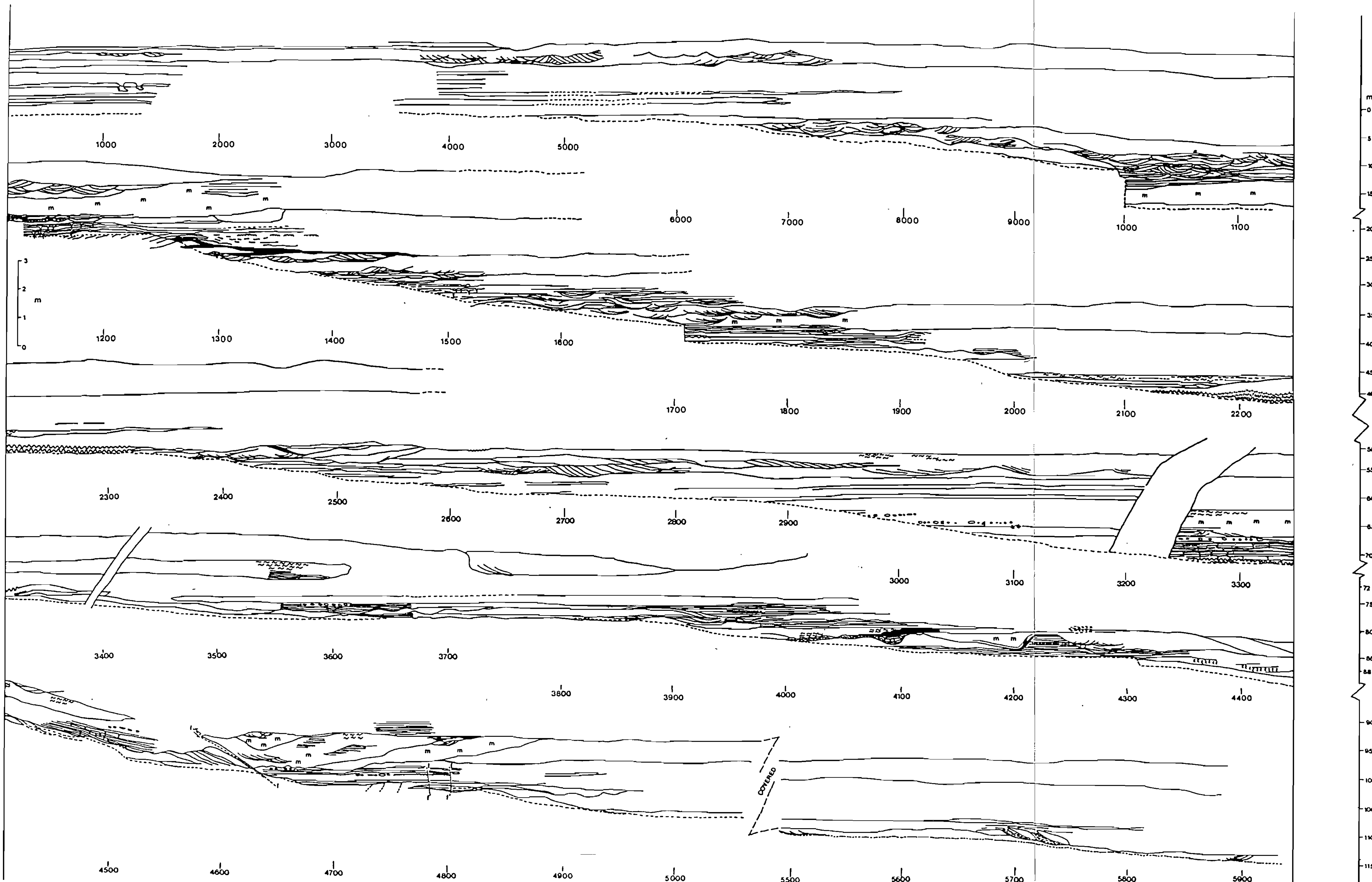
APP. FIG.5c

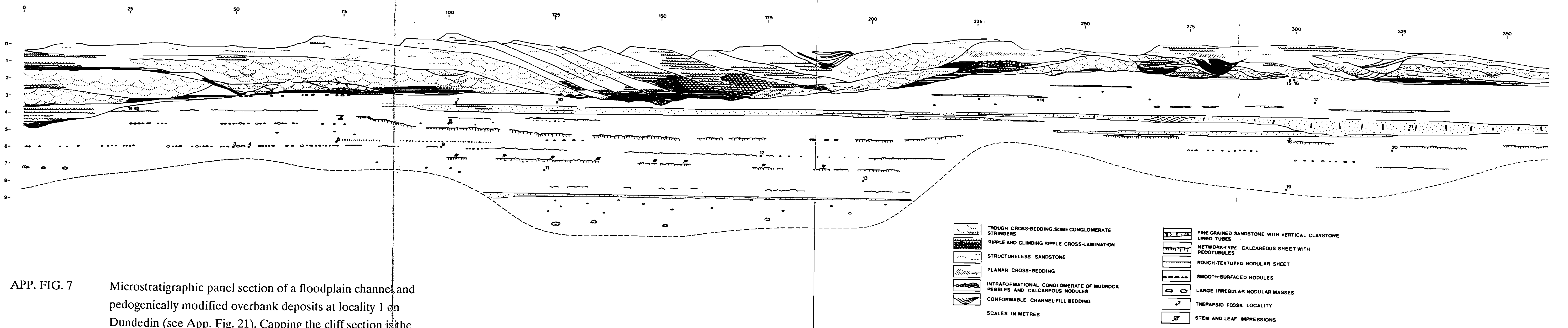




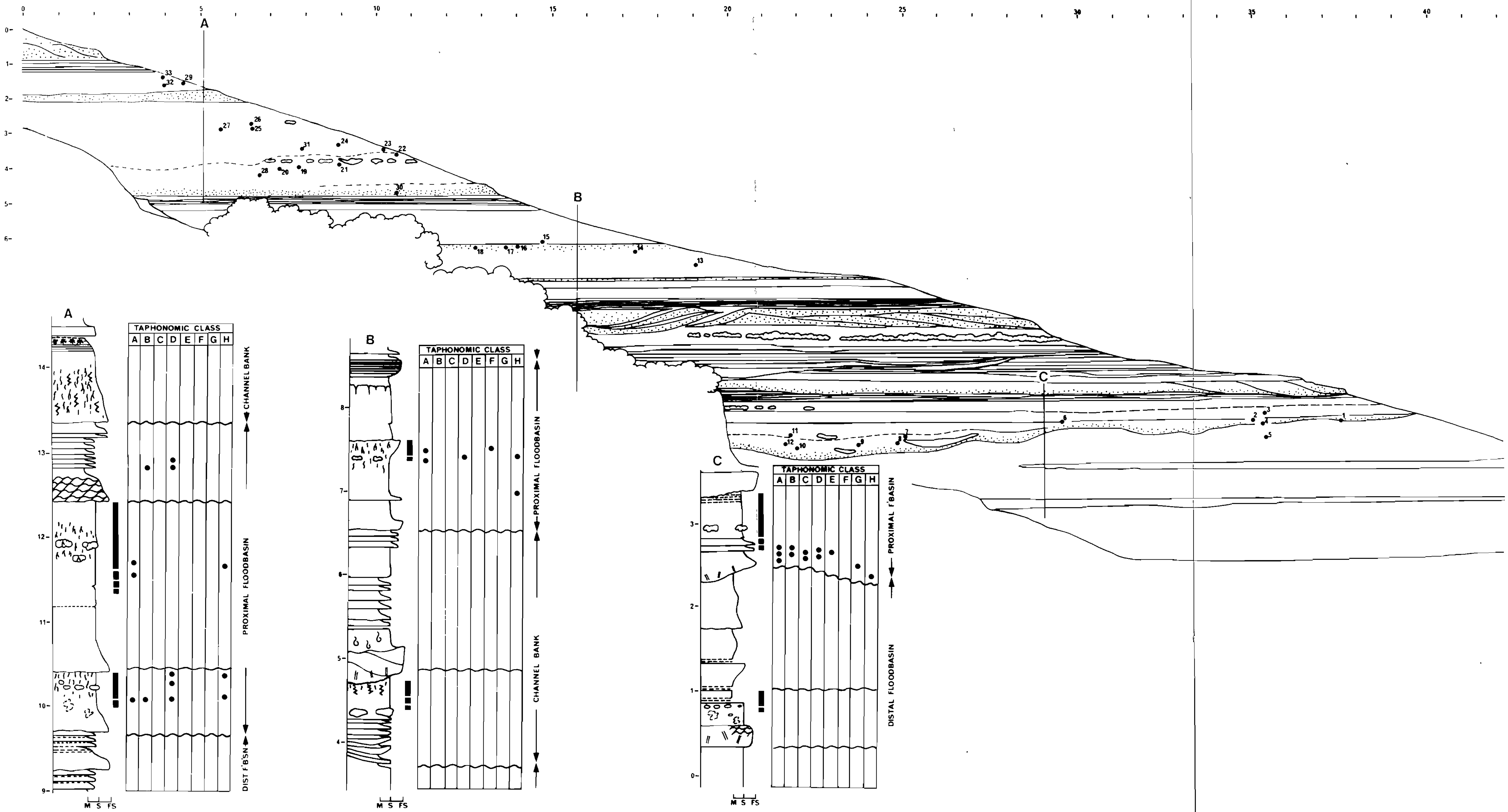
LONGITUDINAL AND COLUMNAR SECTIONS SHOWING SEDIMENTARY STRUCTURES OF A CLIFF EXPOSURE ON WATERVAL : SECTIONS G-H, I-J, K-L

APP. FIG. 6 Continuous tangential panel section through the upper 115 m of Teekloof strata exposed in the bed and banks of the Leeu River on Amandelboom. See App. Fig. 5 for legend, m = massively-bedded sandstone. Details from this section are shown in figures 19, 20, 21, 23, 24, 31, 32, 33, 34 & 39.

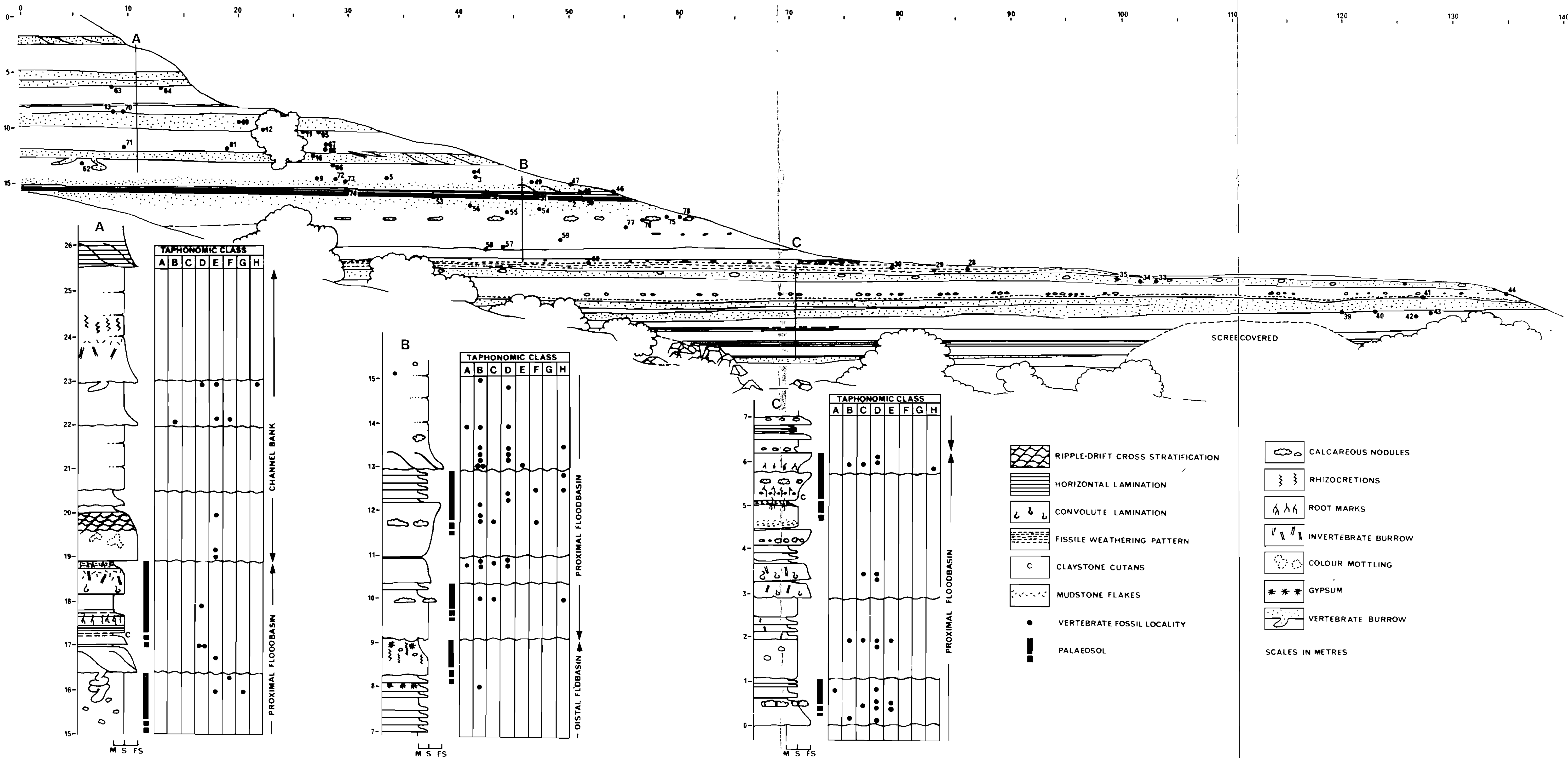




APP. FIG. 7 Microstratigraphic panel section of a floodplain channel and pedogenically modified overbank deposits at locality 1 on Dundedin (see App. Fig. 21). Capping the cliff section is the remnants of a small-scale meandering channel with distinctive high angle lateral accretion surfaces (epsilon cross-bedding). Palaeoflow directions are towards the reader. Note the lateral continuity and topography of the underlying palaeocaliche horizons and the apparent bifurcation of the rooted crevasse-splay sandstone as it pinches out.



APP. FIG. 8 Microstratigraphic panel section and detailed columnar logs of an exposure of interchannel deposits on Leeukloof 402 (Locality 1 of Fig. 9) showing the bedding characteristics, palaeosols and distribution and taphonomy of vertebrate fossils. Refer to App. Fig. 9 for legend.



APP. FIG. 9 Microstratigraphic panel section and columnar logs of a cliff exposure of interchannel deposits on Wilgeboschkloof (see Fig. 6 for locality) showing bedding, palaeosols and the distribution and taphonomy of vertebrate fossils.

APP. FIG. 10 Plan of the levee sandstone palaeosurface exposed on Vaalkoppies, near Beaufort West. Note how the dendritic rills follow the troughs of the primary ripple trend. Most of the other marks are either prod, skip or scrape marks made by floating vegetation and biogenic trails of various kinds (see Figs. 25, 26, 27 & 28). Scale in metres.

APP. FIG. 11 Graphic log of lithologies sedimentary sequences and palaeosols of a 28 m stratigraphic succession exposed on Amandelboom at locality of fossils K6730 - 32 (see App. Fig. 20).

APP. FIG. 12 Graphic log of lithologies, sedimentary sequences and palaeosols of a 16 m section exposed on Amandelboom at the locality of fossils K6558 - 72 (see App. Fig. 20).

APP. FIG. 13 Graphic log of lithologies, sedimentary sequences and palaeosols of an 18 m succession exposed on Reiersvlei at the locality of fossils K6734 - 42 (see App. Fig. 20).

APP. FIG. 14 Graphic log of lithologies, sedimentary sequences and palaeosols of a 23 m succession exposed on Bergvallei near the locality of fossil K6866 (see App. Fig. 20).

APP. FIG. 15 Graphic log of lithologies, sedimentary sequences and palaeosols of a 21 m succession exposed on Willowdene (Teekloof Pass, see App. Fig. 19) at the locality of fossils K6652 - 70.

APP. FIG. 16 Graphic log of lithologies, sedimentary sequences and palaeosols of a 23 m succession exposed in Teekloof Pass (see App. Fig. 19) at the locality of fossils K6836 - 40 and 6956 - 60.

APP. FIG. 17 Graphic log of an 11 m succession exposed at L19 on Dundedin (see App. Fig. 21) showing the lithologies, sedimentary sequences and palaeosols.

APP. FIG. 18 Graphic log of lithologies, sedimentary sequences and palaeosols of a 6.5 m succession at L22 on Rosedene (see App. Fig. 21).

APP. FIGS 11-18
LEGEND

SEDIMENTARY STRUCTURES

- Trough cross bedding
- Horizontal laminae
- Ripple cross-laminae
- Climbing ripple cross-laminae
- m m Massive bedding
- Convoluted laminae
- Intraformational mudrock pebble and glaebule conglomerate

PEDOGENIC FEATURES

- Rhizocretions
- Root channels
- Cluster of smooth-topped nodules
- Discrete rough-surfaced nodules
- Isolated irregular shaped nodules
- Discrete smooth-surfaced nodules
- Slickensided "skew" planes
- "Rotten" shale - ash band?
- Ca Calcareous laminae
- Polygonal network of nodular material
- Septarian nodule

ROCK COLOUR

1 = Black
2 = Dark grey
3 = Grey
4 = Greenish-grey
5 = Green
6 = Greyish-brown
7 = Brown
8 = Reddish-brown
9 = Cream
||||||| = Dark reddish-brown
(5) = Mottled (green)

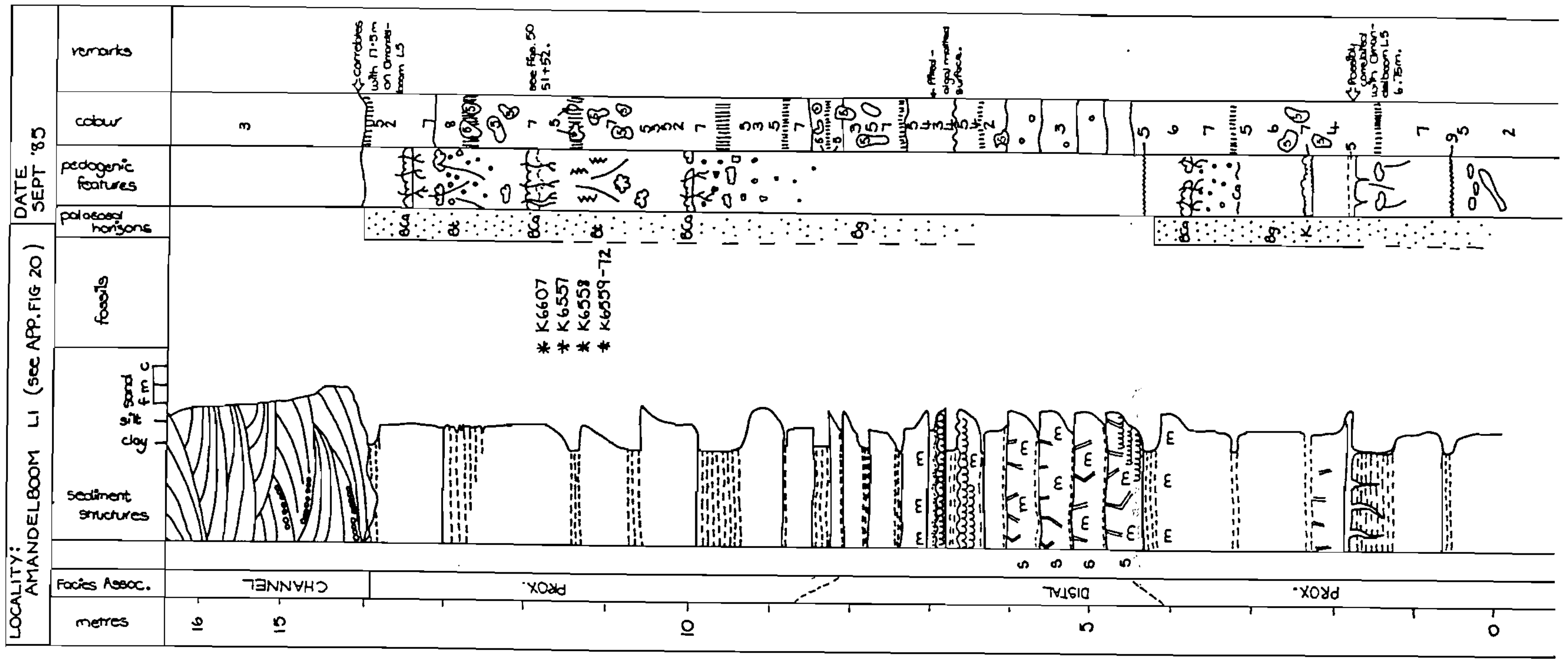
PALAEOSOL HORIZONS

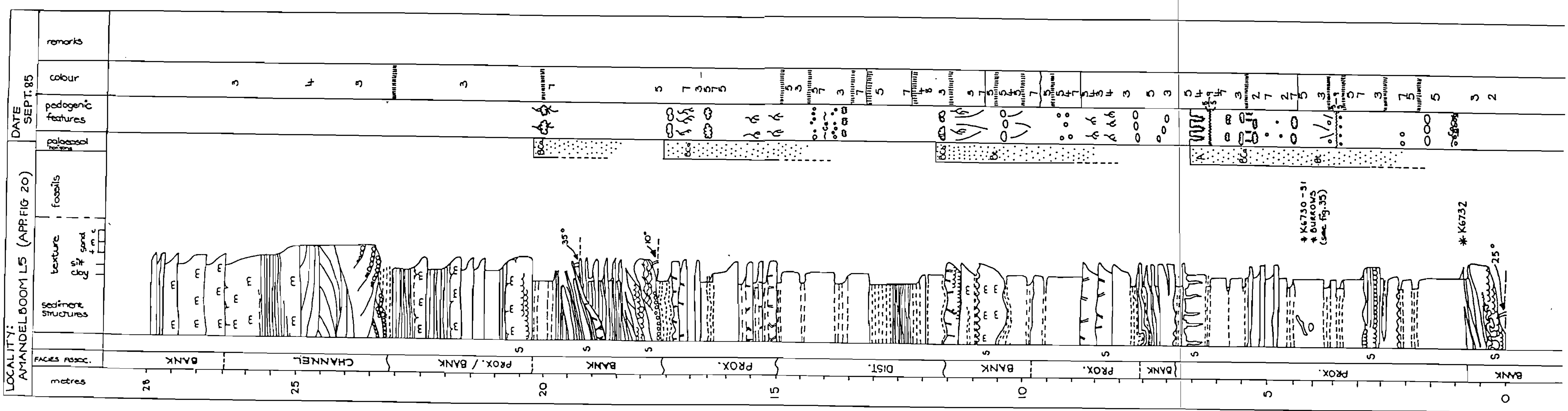
BCa = Calcareous B
Bt = Textural B
Bg = Gleyed B
C = Parent alluvium
K = Calcareous duripan
P = Palustrine carbonate

FOSSILS

- Therapsid fossils
- Invertebrate burrows
- Vertebrate burrows
- Plant impression

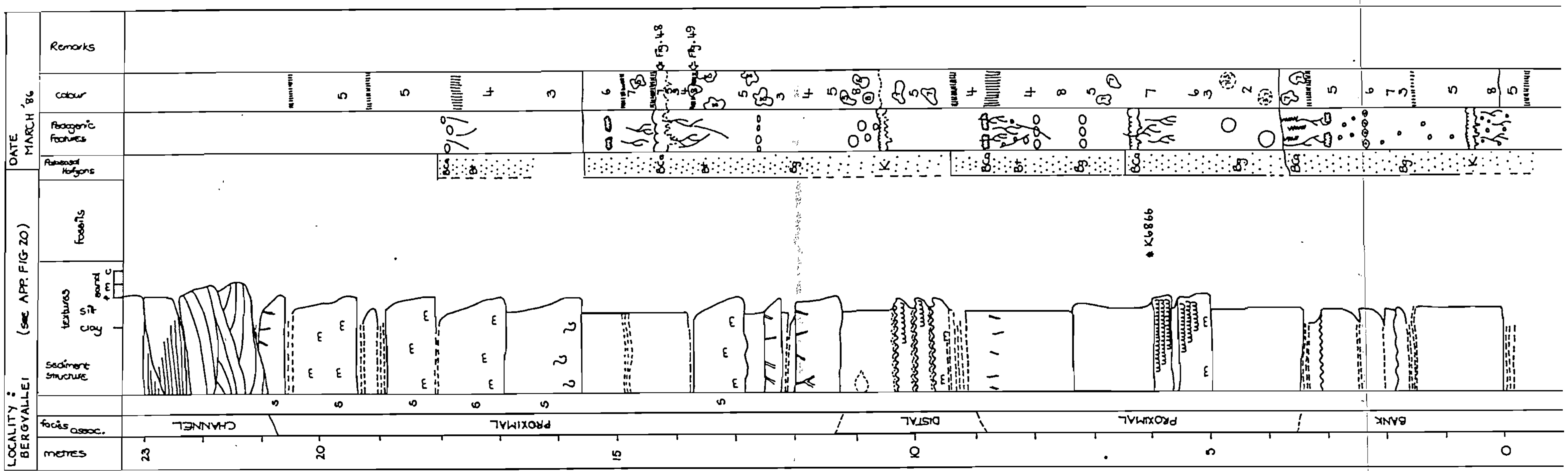
APP. FIG. 12 Graphic log of lithologies, sedimentary sequences and palaeosols of a 16 m section exposed on Amandelboom at the locality of fossils K6558 - 72 (see App. Fig. 20).

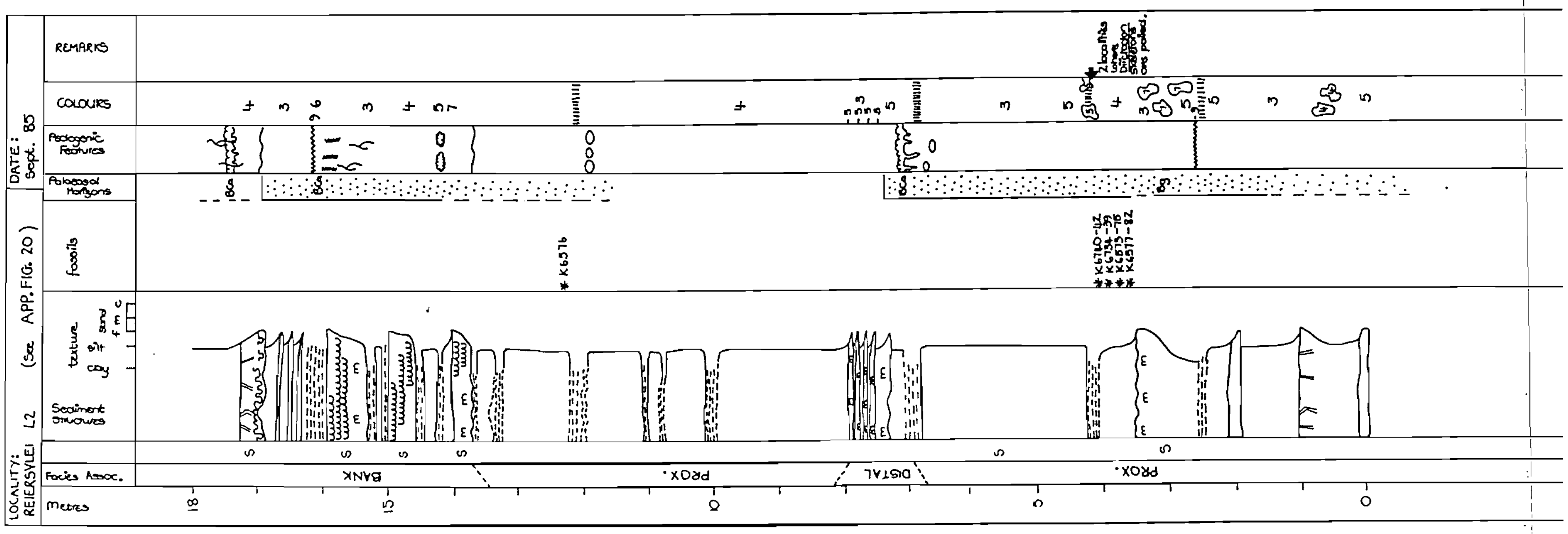




APP. FIG. 11 Graphic log of lithologies sedimentary sequences and palaeosols of a 28 m stratigraphic succession exposed on Amandelboom at locality of fossils K6730 - 32 (see App. Fig. 20).

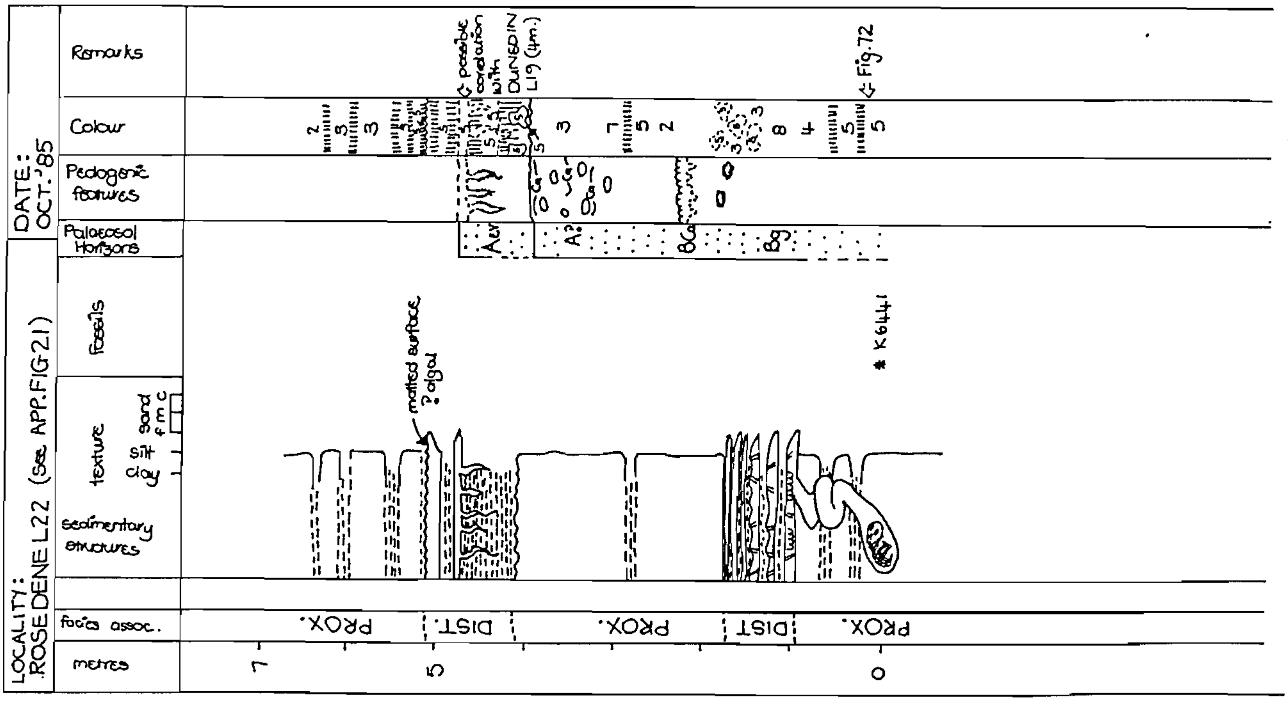
APP. FIG. 14 Graphic log of lithologies, sedimentary sequences and palaeosols of a 23 m succession exposed on Bergvallei near the locality of fossil K6866 (see App. Fig. 20).

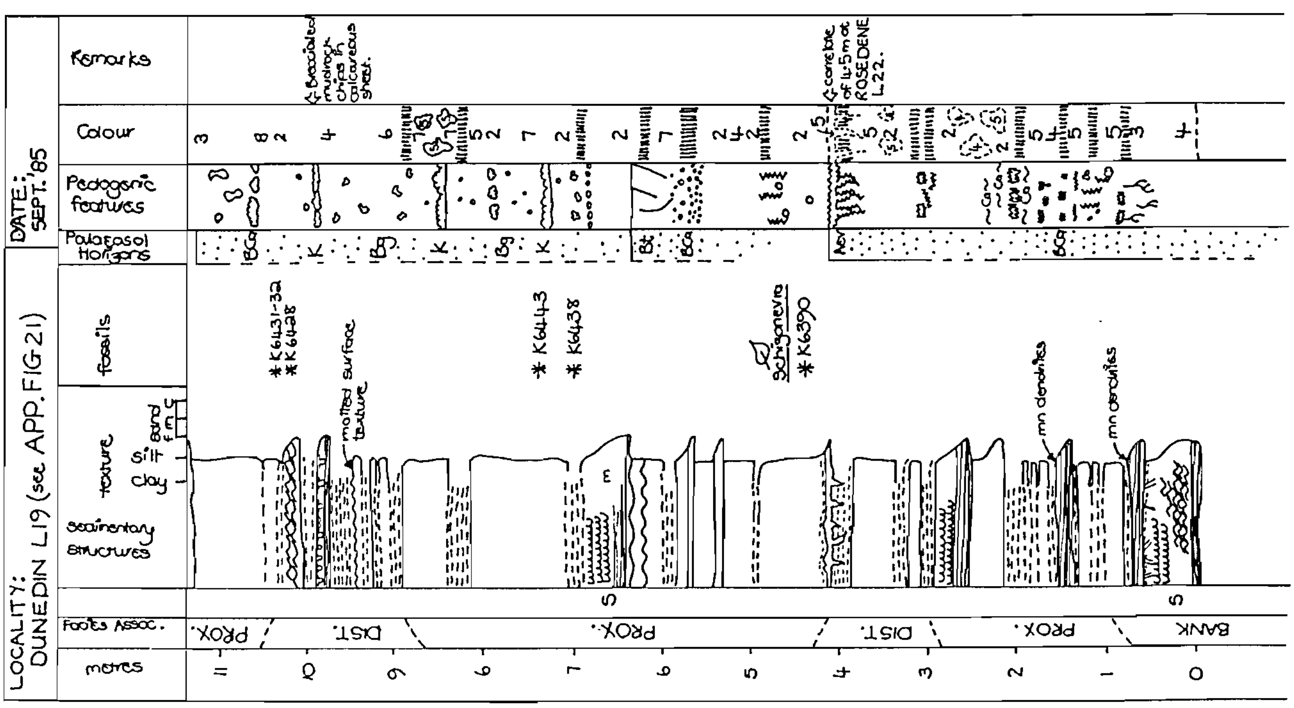




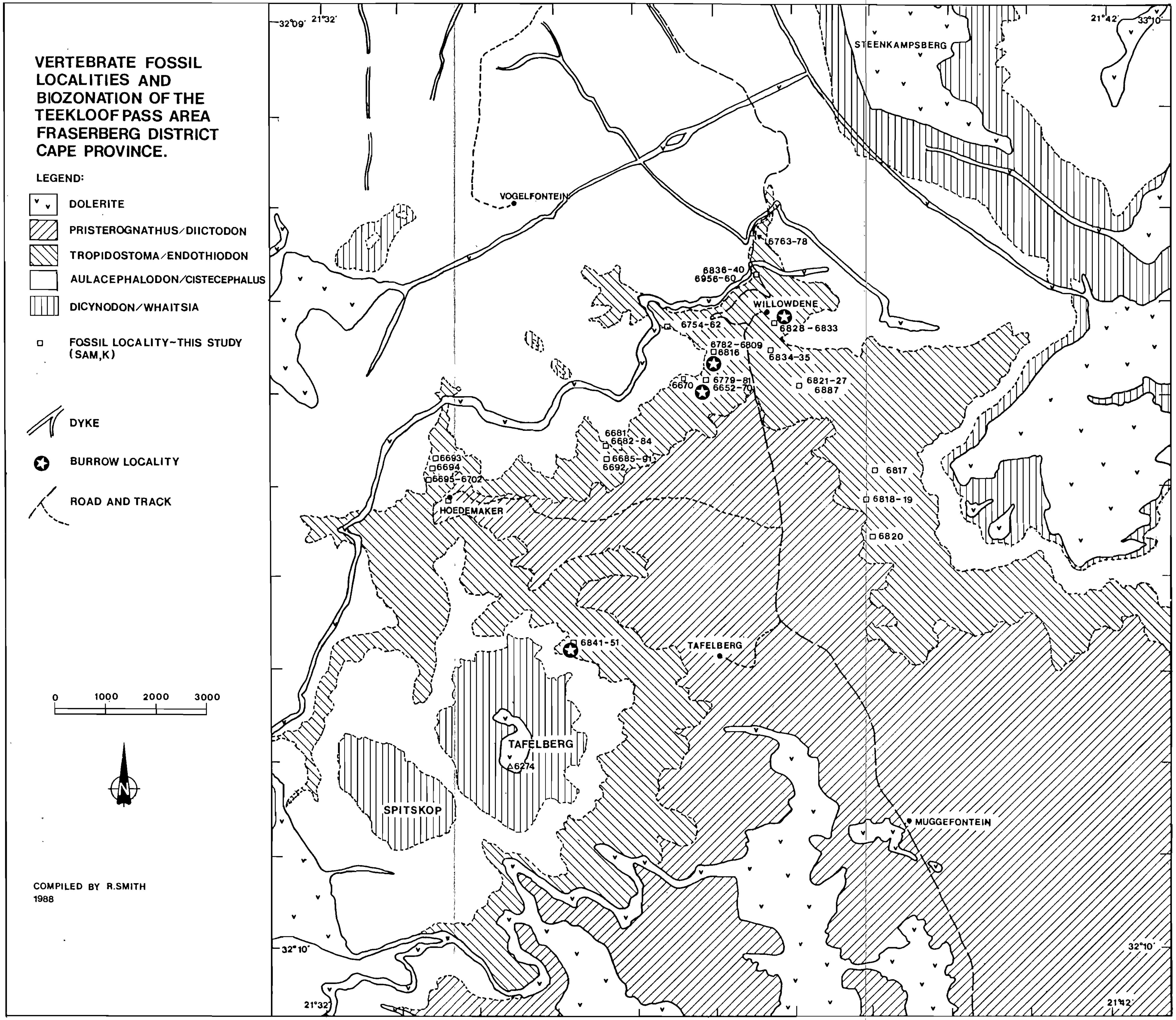
APP. FIG. 13 Graphic log of lithologies, sedimentary sequences and palaeosols of an 18 m succession exposed on Reiersvlei at the locality of fossils K6734 - 42 (see App. Fig. 20).

APP. FIG. 18 Graphic log of lithologies, sedimentary sequences and palaeosols of a 6.5 m succession at L22 on Rosedene (see App. Fig. 21).



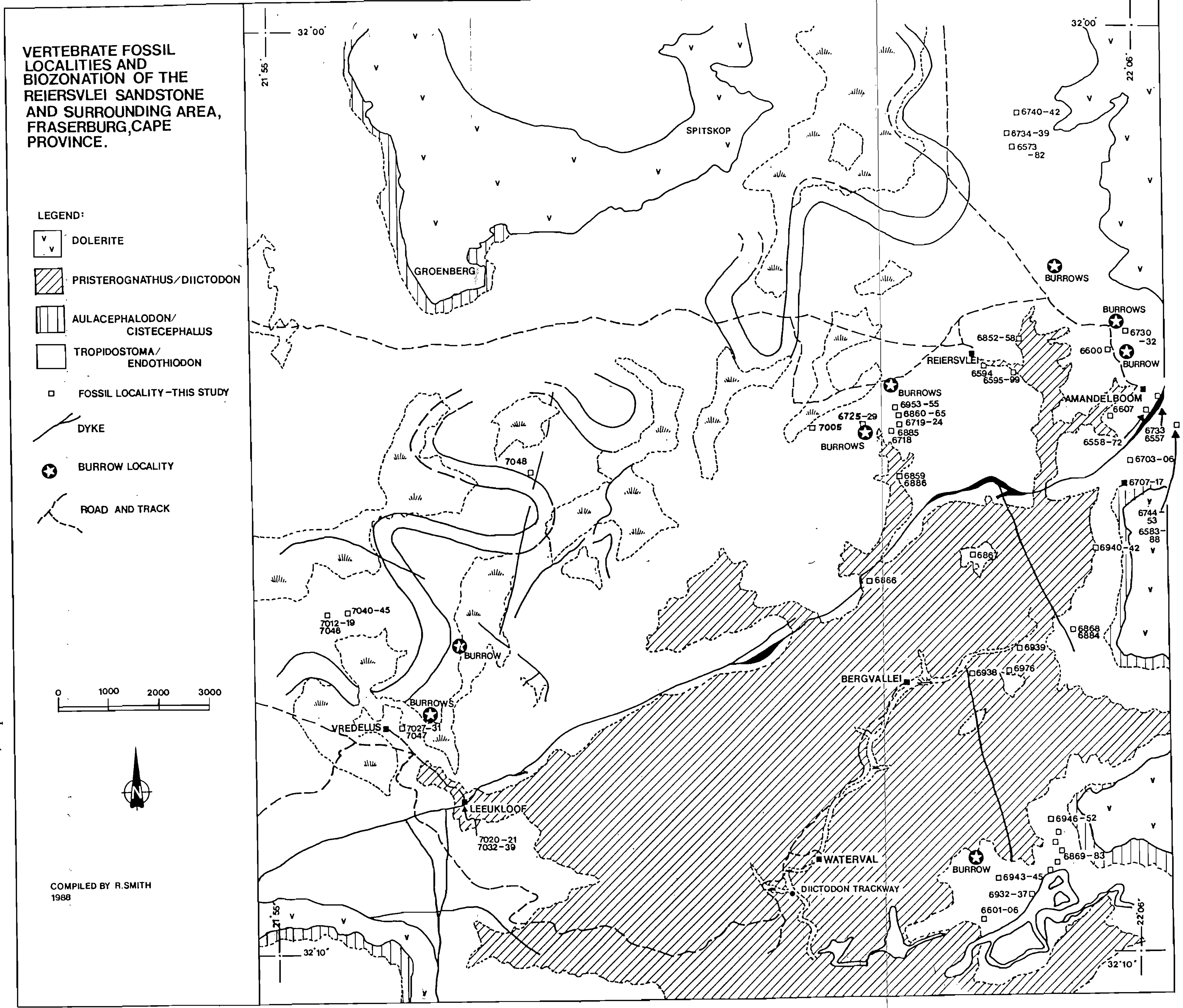


APP. FIG. 17 Graphic log of an 11 m succession exposed at L19 on Dunedin (see App. Fig. 21) showing the lithologies, sedimentary sequences and palaeosols.

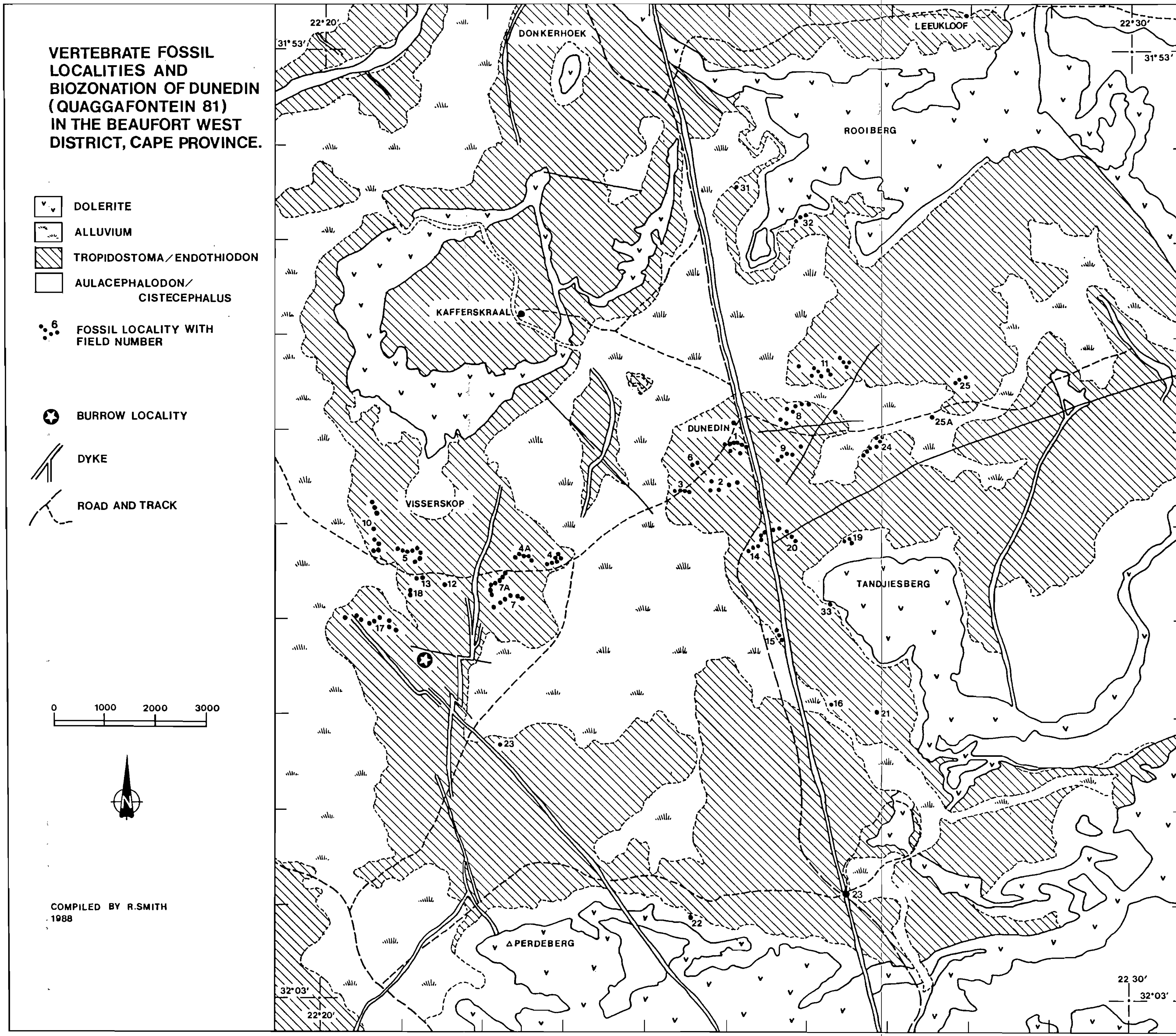


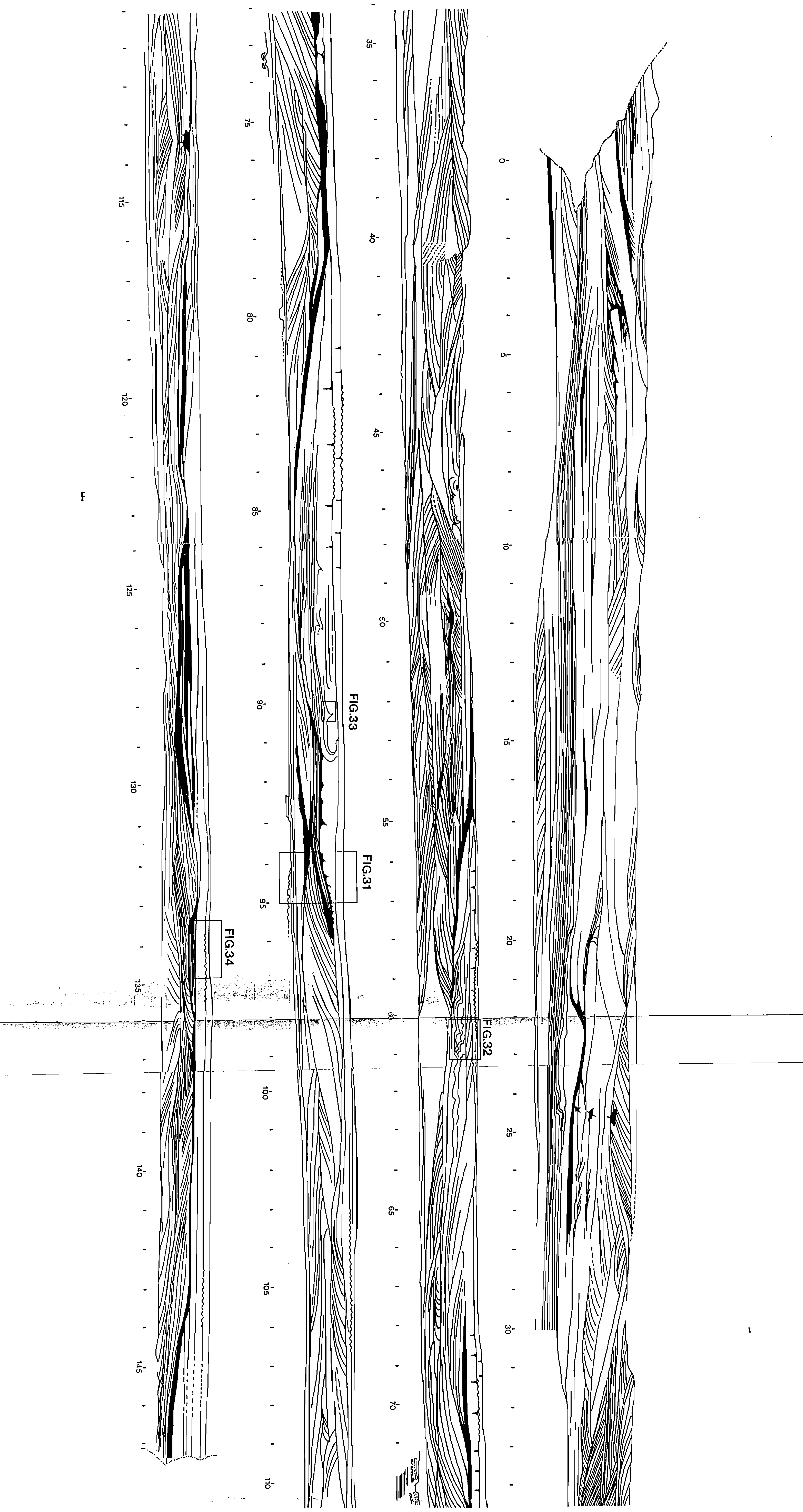
APP. FIG. 19 Vertebrate fossil localities and biozonation of the Teekloof Pass area, Fraserburg district, Cape Province.

APP. FIG. 20 Vertebrate fossil localities and bizonation of the Reiersvlei sandstone and surrounding area, Fraserburg district, Cape Province.



APP. FIG. 21 Vertebrate fossil localities and biozonation of Dunedin (Quaggafontein 81) in the Beaufort West district, Cape Province.





APP. FIG. 22 Bedforms and bounding surfaces in a cliff section of a single crevasse-splay sandstone outcropping in the Leeu River banks on Amandelboom between metres 3600 and 3450 of App. Fig. 6.

APP. FIG. 23 Summary sheets of taphonomic data collected at the locality of every fossil recovered from the three study areas during the course of this investigation and taken into the collections of the South African Museum, Cape Town.

TAPHONOMIC DATA SHEET FOR ....Dunedin.................... STUDY BLOCK

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5032	Diictodon	Dunedin	6	Tropid/Endo	D	Dorso-lateral	Nod	4	white	maroon grey/green mottled	mud	90	✓	A
5033	Dicynodont	"	6	"	D	lat-up	Nod	2	white	grey/maroon	silt	–	✓	-
5034	Dicynodont	"	5	"	C	?	Nod	2	cream	grey/green	mud	–	x	-
5035	Dicynodont	"	5	"	B	lat up	Ca lam	2	white	grey/maroon	silty mud	91	✓	A
5036	Pristerodon	"	6	"	D	lat up	None	4/5	brown	maroon	mud	61.5	✓	A
5037	Pristerodon	"	5	"	E	dors-up	Nod	3	white	grey	mud	78.5	✓	A
5038	Diictodon	"	5	"	E	dors-up	Nod + mud chip	2	cream	grey	silty mud	75.0	x	A
5039	Pristerodon	"	5	"	C	vent-up	Nod	4	white	grey green	silt	72.0	✓	A
5040	Diictodon	"	5	"	E	lat-up	None	2	cream	grey green	mud*	80.5	✓	A
5041	Diictodon	"	5	"	D	lat-up	None	5	cream	grey green	silt	74	✓	A
5042	Diictodon	"	5	"	D	lat-up	Calam + nod	5	white	grey green	silty mud	76	x	A
5043	Diictodon	"	5	"	E	dors-up	none	2	white	green	silt	?	✓	A
5044	?	"	5											
5045	bones indet	"	5	"	–	–	nod	4	white	purple	mud	–	-	-
5046	dicynodont	"	3		C	dors-up	nod	2	white	green brown	silt	76	x	?
5047	dicynodont	"	3	"	F	–	nod	2	cream	grey green	silt.	–	–	-
5048	Diictodon	"	2	"	-	-	nod	2	cream	grey green	mud	–	✓	-
5049	Dicynodont	"	5	"	E	dors-up	none	4	cream	green	silt	–	✓	-

SAM = SOUTH AFRICAN MUSEUM, CAPE TOWN I = Infant J = Juvenile A = Adult

GSO = GEOLOGICAL SURVEY OF SOUTH AFRICA, PRETORIA

TAPHONOMIC DATA SHEET FOR ....DUNEDIN.................. STUDY BLOCK Page ..2...... of ....

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5050	Pristerodontinid	Dunedin	2	Tropid/Endo.	E	dors-up	Nod.	2.	white	maroon	mud	–	X	–
5051	Diictodon	"	2		D	lat.up	none	4	brown	grey	mud	–	✓	–
5052	Oudenodon	"	2		F	indet.	Nod.	4	white	brown	?	–	–	–
5053	Dicynodont	"	2		E	indet.	Nod.	4	white	brown	calc. nod.	64	X	A
5054	Diictodon	"	2		E	lat:up	Ca.mud	2	white	grey	mud.	21	✓	I
5055	Dicynodont	"	2		E	dors-up	None	4	white	maroon	mud.	–	–	–
5056	Dicynodont	"	2		E	indet.	Ca.mud	2	brown	grey brown	mud.	–	–	–
5057	Diictodon	"	2		D	vent-up	Ca.mud + nod.	4	white	green	mud.	–	X	–
5058	Diictodon	"	2		D	dorso-lat. up	Nod.	indet.	white	maroon green	Ca. nod. mud.	60	X	A
5059	Diictodon	"	2		E	dors. -up.	Ca.nod.	2	white	maroon green	mud	80,5	X	A
5060	Diictodon	"	2		E	Dors. lat: up	Ca.nod.	indet.	white	green maroon mottled	mud	–	✓	–
5061	Diictodon	"	2		E/F?	indet.	Nod.	4	grey brown	grey maroon	silt ca.nod	–	✓	–
5062	Post cranial (indet.)	"	49		B/G?	indet.	Ca.mud	1	cream	green	mud	–	–	–
5063	Pristerodontinid	"	4		E	?	Nod.	?	white	brown	ca.mud.	50	X	J
5064	Dicynodont	"	4		E	indet.	Nod.	2	white	grey brown	mud.	–	✓	–
5065	Oudenodon	"	5		E	dors:up	Ca.mud + Ca. lam	2	cream	green	mud.	–	X	–
5066	Diictodon	"	5		D.	dors.-up	None	2	cream	green	silt.	62	indet.	A
5067	Dicynodont	"	5		D	vent-up	Ca.mud	4	white cream	grey	mud.	80,5	✓	A

SAM = SOUTH AFRICAN MUSEUM, CAPE TOWN

GSO = GEOLOGICAL SURVEY OF SOUTH AFRICA, PRETORIA

I = Infant J = Juvenile A = Adult

TAPHONOMIC DATA SHEET FOR ....DUNEDIN........................ STUDY BLOCK

CAT. NO. SAM - K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5068	Diictodon	Dunedin	5	Tropid./Endo.	E	dors-up	None	2	white	grey	co. lam. mud.	indet.	✓	–
5069	Dicynodont	"	5		E	Ventro. lat.	None	4	white	grey	mud	obsc.	X	–
5070	Diictodon	"	5		D	vent.-up	None	4	cream	grey	mud	±95	✓	A
5071	Diictodon	"	5		E	vent.-up	co. silt.	4	brown white	grey	silt.	67	X	A
5072	Dicynodont	"	5		E	dors-up	None	2	white	grey black	mud.	–	X	–
5073	Diictodon	"	5		D	lat.-up	None	2/3	cream	grey	mud.	72	X	A
5074	Pristerodontinid	"	5		C	dors-up	None	2	white	grey maroon	mud	±40	obsc	J
5075	Diictodon	"	5		C	lat.-up	nod. mat.	2	brown	grey	co. lam. mud.	83	X	A
5076	Dicynodont	"	5	"	B	dors-up	None	–	white	green	silt	–	indet.	–
5077	Diictodon	"	5		D	lat.-up	co. lam	2	white cream	grey	co. lam. mud.	±72	✓	A
5078	Diictodon	"	5		E	dors-up	None	2	white	grey	mud.	61	X	A
5079	Diictodon	"	5		D	lat.-up	part. nod.	4	cream	grey black	co. lam. mud	–	✓	–
5080	Dicynodont	"	5		D	vent-up	Nod.	2	white	grey	co. nod	72.5	✓	A
5081	Diictodon	"	4		E ?	indet.	Nod.	4	white cream	grey green	silt.	–	✓	–
5082	Pristerodontinid	"	4		E	dors-up	Nod.	4	white	brown grey	co. nod silt.	–	X	–
5083	Diictodon	"	4		E	dors-up	Nod.	4	white	grey green	co. nod. silt	indet.	X	–
5084	Dicynodont?	"	5	"	indet.	lat. up	None	–	white	grey	mud	–	–	–
5085	Diictodon		4	"	E	dors-up	Nod.	2	white	grey	mud	76	X	A

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TAPHONOMIC DATA SHEET FOR .....DUNEDIN..................... STUDY BLOCK

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5086	Diictodon	Dunedin	4	Tropid./Endo	D/F	lat.-up	cal.nod + cal.lam	2	white	maroon grey	Ca.nod. mud.	–	✓	–
5087	Diictodon	"	5		E/F	dors.-up vent.-up	part.nod.	2	cream	grey	silty mud.	–	X	–
5088	Diictodon	"	5		B	vent.-up	Nod.	4	cream	grey	calc. nod mud.	85	X	A
5089	Pristerodontinid	"	5		E	dors.-up	Globulic nod.mat.	4	brown	brown grey	ca.mud	–	–	–
5090	Dicynodont	"	5		D	lat.-up	nod.	2	white	grey maroon mottled	silt	–	✓	–
5091	Dicynodont	"	5		D	dors-up	nod.	4	white	grey	ca.nod.	80	X	A
5092	Dicynodont	"	5		D	lat.-up	nod.	4	white	grey	silt	–	X	–
5093	Dicynodont	"	5		E	dors.-up	nod.	4	grey white	grey	silt	–	✓	–
5094	Dicynodont	"	5		D	lat.-up	nod.	4	white	grey	silt	–	✓	–
5095	Dicynodont	"	5		E	dors-up	ca.lam.	2	cream	grey	ca.lam. mud	82,5	X	A
5096	Dicynodont	"	5		E	dors-up	ca.lam +nod.mat	2	white	grey green	mud	–	✓	–
5097	Diictodon	"	4	"	D	dors-up	ca.lam. +nod.mat	indet	white	green maroon	mud. ca.nod.	88	✓	A
5098	Dicynodont	"	5		D	lat-up	nod.	2	white	grey	mud.	–	✓	–
5099	Diictodon	"	4		E	indet.	nod.	4	white	grey brown	ca.nod	–	–	–
5100	Post cranial (indet)	"	4a		G	N/A	ca.mud	–	cream	grey	Ca.nod. mud.	–	–	–
5101	Post cranial skeleton (indet)	"	4		?	?	ca lam + nod mat.	2	cream	grey green	silt.	–	–	–
5102	Dicynodont	"	4		E	?	nod.	4	white	grey	silt.	obsc	obsc	–
5103	Diictodon	"	4a		F	dors.-up	ca.lam.	2	white	grey	mud	–	–	–

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TAPHONOMIC DATA SHEET FOR ......DUNEDIN...................... STUDY BLOCK

CAT. NO. SAM-K.	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5104	Diictodon	Dunedin	4	Tropid./Enda.	E	dors-up	Ca mud nod	4	white	maroon	mud.	–	X	–
5105	Diictodon	"	4											
5106	Diictodon	"	4		E	dors-up	Ca. silt. nod	4	white	grey green	silt ca. nod	–	✓	–
5107	Diictodon	"	4		E	dors-up	ca. nod	4	cream	grey/green maroon mottled	mud	–	✓	–
5108	Dicynodont	"	4		B	vent-up	none	4	cream	grey green	mud	obsc	?	–
5109	Diictodon	"	4	"	E	lat-up	nod.	4	white	grey green	mud	76	X	A
5110	Diictodon	"	4		D	lat-up	Ca nod. mud	2/3	white	grey	mud	indet	✓	–
5111	Diictodon	"	4		E	lat-up	nod.	4	white	green grey	Ca. nod. silt.	± 77	✓	A
5112	Dicynodont (10 skulls)	"	4	"	x4 D → x3 E →	lat-up dors-up	nod.	4	cream	grey	mud.	–	✓ x1 X x6	–
5113	Diictodon	"	4		E	dors-up	(1 side) nod.	2	white	grey	silt.	–	✓	–
5114	Dicynodont	"	4		C	?	None	5	cream	green	silt.	obsc	✓	–
5115	Dicynodont	"	4a		D	lat-up	nod.	obsc.	white	green	mud.	–	–	–
5116	Gorgonopsian?	"	4a		?	?	?	?	?	?	?	?	?	?
5117	Dicynodont	"	4a		?	?	nod.	5	white cream	grey green	mud.	–	–	–
5118	Pristerodontid	"	4a		E	lat-up	None	4	white	grey	mud	–	X	–
5119	Post crania	"	2		?	?	Nod. mud	4	white	maroon	mud.	–	–	–
5120	Post crania	"	1		?	?	Nod.	?	cream	grey green	Ca. nod.	–	–	–
5121	Post cranial	"	4a		?	?	None	2	white	grey	Ca. lam silt.	–	–	–

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TAPHONOMIC DATA SHEET FOR ......DUNEDIN.................. STUDY BLOCK

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5122	Dicynodont	Dunedin	4a	Tropid./Endo	H	?	None	1	cream	grey	mud.	—	—	—
5123	Diictodon	"	2		E	indet.	Nod.	4	white	brown grey	mud.	—	✓	—
5124	Dicynodont	"	1		E	dors-up	complete nod. mat.	indet.	indet.	grey green	ca. nod mud.	75	indet	A
5125	Dicynodont	"	4a		?	?	Nod.	5	white	grey green	ca. nod. mud.	—	✓	—
5126	Pristerodontinid	"	4		E	dors-up	nod. mat	4	white	brown	ca. nod.	—	✓	—
5127	Pristerodontinid	"	1		D	lat-up	Postular nod. mat.	4	cream	grey	ca nod. silt	—	—	—
5128	Dicynodont	"	4		E	dors-up	Nod.	4	white	grey brown maroon	ca. nod. mud	—	✓	—
5129	Diictodon	"	4		C	lat.-up	None	2	grey	grey	silty mud.	±70	X	A
5130	Diictodon	"	4		D	lat-up	Nod	4	white	grey	mud	—	✓	—
5131	(cotylosaur?)	"	2											
5132	Diictodon	"	4		D	lat-up	Nod.	2	white	grey	ca. nod. ca. lam. mud.	83	✓	A
5133	Dicynodont	"	3		E	dors-up	None	5	"	green	silt.	87,5	obsc.	A
5134	Dicynodon	"	3		E	indet.	Nod.	4	white	grey brown maroon	mud.	±68	X	A
5135	Diictodon	"	3		B/E	Vent-up	None	5	cream	brown maroon	silt.	indet	✓	—
5136	Bone (indet)	"	4		H	?	ca. silt.	?	?	green	silt	?	?	?
5137	Pristerodontinid	"	2		G	indet	ca. lam. nod.	5	white	brown maroon	ca. nod.	—	—	—
5138	Dicynodont (2 occiputs)	"	3		?	?	None	4	white	green grey	silt.	—	—	—
5139	Diictodon	"	2		E/F	dors-up	nod	4	white	grey	ca. nod	—	—	—

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TAPHONOMIC DATA SHEET FOR ......DUNEDIN...................... STUDY BLOCK

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5140	Diictodon	Dunedin	2	Tropid./Endo.	E	dors.-up	Nod. (upper) ca. lam. (lower)	2	cream	grey	ca. lam. mud	63	X	A
5141	Diictodon	"	2	|	D	lat.-up	nod.	2	white	grey/green maroon mottled	mud	—	✓	—
5142	Diictodon	"	4	|	E	dorso. lat.	nod.	indet.	white	grey	ca nod mud	88,5	✓	A
5143	Pristerodontinid	"	4	|	C	dors-up	?	4	white	grey	ca. nod mud	61,5	X ?	A
5144	Dicynodont	"	3	|	E	dors-up	None	?	?	grey green	silt	—	—	—
5145	Post. crania	"	4	|	?	?	ca. mud.	2	cream	grey maroon	mud	—	—	—
5146	Pristerodontinia	"	3	|	E	dors-up	nod	4	white	grey	silt.	82	✓	A
5147	Dicynodont	"	3	|	D	lat.-up	None	2	cream	grey green	silt.	—	X	—
5148	Diictodon	"	4	|	D	dors-up	ca. lam. + ca. mud.	2	white	grey green	ca. lam. mud.	95,5	✓	A
5149	Dicynodont	"	4	|	indet.	indet.	nod.	?	white	grey	silty mud.	—	—	—
5150	Dicynodont	"	4	|	B	indet.	ca. lam.	2	white cream	grey	ca. lam.	indet.	✓	—
5151	Pristerodontinia	"	3	|	E	vent-up	nod.	2	white	brown	ca nod.	—	✓	—
5152	Diictodon	"	3	|	E	dors.-up	ca. nod. mat.	4	white	grey maroon	silt.	75,5	X	A
5153	Pristerodontinid	"	3	|	D	lat-up	nod.	4	white	brown grey	ca. nod. mud.	—	—	—
5154	Dicynodont	"	3	|	D	dors-up	nod	2	white	grey	silt.	—	—	—
5155	Diictodon	"	3	|	?	?	ca. sst.	?	white	grey green	silt.	±79	✓	A
5156	Post crania	"	2	|	indet.	—	nod	2	white	grey → / brown maroon? →	mud / ca. nod	—	—	—
5157	Post crania	"	1	|	indet.	indet.	nod.	2	cream	grey	silt. ca. nod	—	—	—

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TAPHONOMIC DATA SHEET FOR DUNEDIN STUDY BLOCK

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5158	Diictodon	Dunedin	3	Tropid./Endo.	E	dors-up	Ca mud.	4	cream brown	grey green	ca. lam mud.	73,5	X	A
5159	Pristerodont	"	2		D	lat-up	nod.	2	white	maroon	Ca nod.	—	X	—
5160	Dicynodont	"	1		D	lat-up	nod	—	grey	grey	silt.	—	—	—
5161	Post cranial	"	1		B?	N/A	nod	2	white	grey maroon mottled	mud	—	—	—
5162	Post crania	"	1		?	?	nod.	?	?	?	?	—	—	—
5163	Dicynodont	"	1		?	?	nod.	4	white	grey	co. lam. mud	—	—	—
5164	Post cranial	"	1		?	?	nod	2	white	green maroon	mud.	—	—	—
5165	Pristerodont	"	1		E	dors-up	co. silt.	5	cream	grey	silt.	60,5	indet	A
5166	Dicynodont	"	2		F	—	nod	2	white	maroon	Ca. nod	—	—	—
5167	Post crania	"	1		indet	indet	nod	?	white	green	ca. nod.	—	—	—
5168	Dicynodont	"	1	"	E/F	dors-up	nod	2	white	grey	ca. nod. mud	63	X	A
5169	Diictodon	"	1	"	D	dors-up	nod.	indet	white	green maroon	mud	69	obsc	A
5170	Oudenodon	"	1		E	dors-up	Ca-nod mat.	5	grey	maroon grey	mud	—	—	—
5171	Diictodon	"	2		E	Dorso lat.	Ca. nod	Indet	indet	maroon	mud	—	X	—
5172	Pristerodontid Dicynodont ?	"	2		D	dors-up	ca. nod	3	cream	grey green	ca. nod	—	✓	—
5173	assorted p.c. bones Bones (indet)	"	2		G	indet.	ca mud	5	white	green maroon mottled	ca. nod. mud.	—	—	—
5174	Bone (indet)	"	2		B?	?	None	1	brown	maroon	mud	—	—	—
5175	Bones (indet)	"	2		B	?	None	2	white	maroon	mud	—	—	—

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TAPHONOMIC DATA SHEET FOR ...DUNEDIN..................... STUDY BLOCK

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5176	Dicynodont (femur)	Dunedin	2	Tropid./Endo	H	?	None	5	brown	indet	indet.	–	–	–
5177	Diictodon	"	2		E	dors-up	nod.	2	white	grey	mud chip. breccia in silt.	–	X	–
5178	Dicynodont	"	2		C	lat-up	nod.	4	white	grey green	mud.	75	✓	A
5179	Pristerodont	"	2		?	?	ca. lam.	2	white	brown grey	mud	–	–	–
5180	Diictodon	"	2		D/E?	dors-up	nod.	4	white	grey	ca nod.	–	X	–
5181	Diictodon	"	2		E	dors-up	none	4	brown	grey	silt.	–	X	–
5182	Gorgonopsian	"	2		?	?	nod	?	white	?	ca nod	–	–	–
5183	Post cranial	"	2		?	?	ca nod	?	?	?	ca nod	–	–	–
5184	Diictodon	"	4a		D	indet.	nod.	4	white	grey	ca. nod. mud.	–	✓	–
5185	Diictodon.	"	2		D	lat-up	none	2	white	grey	ca. lam mud.	74	X	A
5186	Post cranial	"	2		H	indet	none	5	cream	grey green	ca. lam. mud.	–	–	–
5187	Diictodon ?	"	2		D	indet.	none	2	brown	maroon grey	mud	55,5	X	A
5188	amphibian	"	5											
5189	Diictodon	"	4											
5190	Pristerodont	"	5		E	vent-up	nod.	2	white	grey	mud.	91,5	✓?	A
5191	Post cranial	"	3		B?	?	ca. lam	2	white	grey	silt	–	–	–
5192	Diictodon ?	"	3		D	lat-up	none	5	brown	maroon	mud	obsc	✓	–
5193	Post cranial	"	?		?	?	nod.	?	white	grey maroon	ca. nod	–	–	–

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TAPHONOMIC DATA SHEET FOR DUNEDIN STUDY BLOCK Page 10 of ....

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5267	Diictodon	Dunedin	7a	Tropid./Endo	E	lato-ventral	ca. mud	2	grey	grey	mud	71,5	✓	A
5268	Diictodon	"	7a		E	lat-up	ca. mud	4	cream	grey	mud.	85	✓	A
5269	Diictodon	"	7a		D	lat-up	ca. lam	4	white cream	grey	mud.	indet	✓	–
5270	(Kingoria?)		7											
5271	Diictodon	"	7a		D	vent-up	nod	3	white	grey	mud	–	–	–
5272	Diictodon	"	7		F	vent-up	nod	2	cream	grey	ca. nod mud	–	–	–
5273	Diictodon	"	7		D	ventro lat	nod.	2	cream	green grey	silt.	83	✓	A
5274	Diictodon	"	7		B	lat.-up	ca. lam.	4	cream	grey green	ca. lam mud	80	–	A
5275	Dicynodont	"	7a		E	lat-up	?	4	grey	grey	mud	–	✓	–
5276	Dicynodont	"	7		E	dorso lat	ca-lam	2	cream	maroon grey	mud	–	✓ obsc	A
5277	Pristerodontinid	"	7		E	dors.-up	none	4	cream	maroon grey	silt.	indet.	✓ obsc	–
5278	Pristerodontinid	"	7		E	dors-up	ca lam	2	cream	green	mud	62	X	A
5279	Dicynodont	"	7		E	lat-up	nod	?	white	green grey	mud	–	X	–
5280	Dicynodont	"	7a		E/H	vent-up	nod	4	white	grey green	mud	–	✓	–
5281	Diictodon	"	7		E	lat-up	ca. lam	2	green	green	silt	46	X	J
5282	Diictodon	"	7		D	lat-up	ca. mud	2	white	grey green	mud.	72,5	X	A
5283	Gorgonopsian	"	7		E	lat-up	nod.	2	cream	grey	mud	–	✓	–
5284	Diictodon	"	7a		D	lat-up	none	1	cream	grey green	silt.	–	X	–

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TAPHONOMIC DATA SHEET FOR ....DUNEDIN.................... STUDY BLOCK Page ..11....... of ....

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5285	Diictodon	Dunedin	7	Tropid./Endo.	D	lat-up	ca. lam	4	grey	grey	silty mud.	—	✓	—
5286	Diictodon	"	7a		D	lat-up	ca. nod.	2	white	grey	silt	70	X	A
5287	Diictodon	"	7		D	dors-up	none	2	yellow stain white	grey	silt	55	X	A
5288	Oudenodon	"	7		E	lat-up.	nod	2	white	green	mud.	—	indet. ✓	—
5289	? p-c. skeleton	"	7		H	?	nod	2	cream	grey	mud	—	—	—
5290	Dicynodont	"	7a		E	vent-up	nod	4	cream	grey	mud	—	✓	—
5291	Dicynodont	"	7a		E	vent-up	?	4	cream	grey	mud	—	✓	—
5292	Gorgonopsian	"	7a		E/H	vent-up	nod	4	grey	grey	mud	—	indet ✓	—
5293	Dicynodont	"	7a		E	lat-up	nod	2	white	grey black	mud	—	—	—
5294	Dicynodont	"	7		E/F	lat-up	ca. lam	2	white	grey green	mud	—	✓	—
5295	Diictodon	"	7		D	ventro-lat.	ca. lam	2	cream	grey green	mud	obsc	X	—
5296	Pristerodontinid	"	7		E	ventro-lat.	none	4	grey	grey green	mud	indet	indet ✓	—
5297	Diictodon	"	7		E	dors-up	ca. lam	5	white	grey	silty mud.	72.5	X	A
5298	Diictodon	"	7		D	lat-up	none	2	cream	green	mud	obsc.	X	—
5299	Diictodon	"	7		D	lat-up	nod.	4	cream	grey brown	mud. co. nod	—	X	—
5300	Diictodon (3 skulls)	"	7		(1) D/E (2)	lat-up	nod.	2	white	green	ca. nod. silt	—	1x ✓ 2x X	—
5301	Diictodon	"	7		D.	lat-up	nod	obsc.	white	green grey	silt.	118.5	✓	A
5302	Diictodon	"	7		C	vent-up	nod	1	grey	green	silt. lam	84.5	✓	A

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TAPHONOMIC DATA SHEET FOR ....DUNEDIN.................... STUDY BLOCK

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5303	Dicynodont	Dunedin	7a	Tropid./Endo	E			4	white	grey green	mud.	—	—	—
5304	Pristerodontid (skull)	"	7		E	dors-up	nod.	4	white	maroon	mud.	—	X	—
5305	Pristerodontid	"	7a		D	lat-up	nod	4	grey	grey	mud.	—	✓ obsc	—
5306	Diictodon	"	7		—	—	—	—	—	—	—	—	—	—
5307	Diictodon	"	7		D	lat-up	nod.	4	cream	grey	ca nod mud	—	✓	—
5308	Diictodon	"	7		—	—	—	—	—	—	—	—	—	—
5309	Diictodon	"	7		D	lat-up	nod	2	white cream	grey	mud	—	✓	—
5310	Diictodon	"	7			lat-up	ca lam	2	cream	grey	lam. mud	—	✓	—
5311	Diictodon	"	7		D	lat-up	none.	1	grey	grey	mud.	—	X	—
5312	Diictodon	"	7		D	lat-up	nod cal	4	white	light grey	ca. nod.	102,5	✓	A
5313	? articulated skeleton	"	7a		H		nod	2	white	maroon grey	mud.	—	—	—
5314	Dicynodont	"	7a		E	dors-up	ca. lam	4	cream	grey maroon	ca. lam.	—	X	—
5315	Diictodon	"	9		B	lat-up	ca lam	4	cream	grey	mud	—	✓	—
5316	Oudenodon	"	9		E	vent-up	nod.	5	white	grey green	mud.	—	✓	—
5317	Pristerodont	"	9		E\F	vent-up	nod.	4	white cream	grey green	mud.	—	indet ✓	—
5318	Diictodon	"	9		E	dors-up	nod.	4	white	indet	ca. nod	77	X	A
5319	Dicynodonts	"	9		E, F; D → lat-up, F → vent-up	lat-up / vent-up	ca. lam.	4	grey	grey green	mud.	—	1X ✓ 1X X	—
5320	? Therocephalian	"	9		D	lat-up	nod.	4	white	grey	mud	indet	indet	—

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CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5321	Dicynodont.	Dunedin		Tropid./Endo.	E	lat-up	nod.	4	white	grey green	mud.	?indet	✓ obsc	—
5322	Dicynodont (2 skulls)	"	9	|	D	lat-up	co. lam	2	white (orange)	grey maroon	mud.	64	1x ✓	A
5323	Dicynodont	"	9	|	D.E.F.	lat-up	nod.	4	cream	grey green	mud.	obsc	✓	—
5324	Diictodon	"	9	|	D	vent-up post-up	nod.	4	white	grey	lam. mud.	72	?	A
5325	Dicynodont	"	9	|	D	latro-dors.	co. lam.	2	cream grey	grey maroon	mud	?indet	X	—
5326	Diictodon	"	9	|	C	vent-up	nod.	4	cream	grey maroon	mud.	—	✓ obsc	—
5327	Dicynodont.	"	9	|	H, E→	lat-up	nod.	4	cream	grey green	silt.	—	✓	—
5328	Diictodon	"	9	|	E	dors-up	nod	4	cream	grey	mud.	74	✓	A
5329	Diictodon	"	9	|	E	lat-up	nod.	2	cream	grey	mud.	87	✓	A
5330	Diictodon	"	9	|	D	lat-up	nod.	4	white	grey green	mud.	93	✓	A
5331	Scaloposaurid	"	9	|	E	lat-up	nod	4	cream	grey green	mud	—	X	—
5332	Diictodon	"	9	|	A	lat-up	co. lam	1	cream	grey	mud	± 81,5	?	A
5333	Dicynodont	"	9	|	E	dors.-up	co. lam	4		black maroon	mud.	—	✓ indet	—
5334	Diictodon	"	9	|	E → F →	lat.-up vent-up	co. nod	4	cream	green grey	lam. mud.	—	X obsc	—
5335	Scaloposaurid	"	9	|	D	lat-up	nod	2	cream	—	—	obsc	obsc ✓	—
5336	Diictodon	"	9	|	3	lat-up	co. lam	4	cream brown	grey green	mud	—	✓	—
5337	Dicynodont	"	9	|	E.	?	co. lam	4	cream	green	mud	—	X	—
5338	Diictodon	"	9	|	D	dors-up	co. nod	2	cream	grey	mud	—	X	—

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TAPHONOMIC DATA SHEET FOR ....DUNEDIN.................... STUDY BLOCK

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5339	Scaloposaurid	Dunedin	9	Tropid./Endo.	E	lab-up	—	4	grey	grey	mud	51	✓	A
5340	Diictodon	"	9		D	vent-up	nod.	4	cream grey	grey	ca.nod. mud	—	X	—
5341	Diictodon	"	9		D	lat-up	none	2	cream	grey	mud.	—	X	—
5342	Diictodon	"	9		D	lat-up	nod	2	white	grey	silty	—	✓	—
5343	Oudenodon	"	9		E, H	?	ca.lam	4	cream	grey green	mud.	—	✓ indet	—
5344	Oudenodon?	"	9		F	lat-up	nod.	4	white	grey	mud	—		—
5345	Diictodon	"	9		D	ventro-lat	nod	4	white	grey	mud	—	✓	—
5346	Diictodon	"	9		E	lat-up	ca.nod.	2	white cream	grey	mud	indet	x	—
5347	? p-c pieces	"	9		H		nod.	4	white	grey	mud.	—	—	—
5348	Diictodon	"	9		B	lat-up		4	white	grey	mud.	—	X	—
5349	Diictodon	"	9		D	lat-up	ca.mud	4	white cream	grey	mud	82.5	✓	A
5350	Diictodon	"	9		D	vent-up	none	4	white	grey	mud	81	✓	A
5351	Dicynodont	"	9		E\F	lat-up	nod.	4	cream	maroon	mud	obsc	obsc ✓	—
5352	Diictodon	"	9		E	lat-up	nod	4	white	grey	mud	—	✓	—
5353	Diictodon	"	9		E → dors / F → lat.		ca.mud.	2	white	grey	mud.	—	✓	—
5354	Diictodon	"	9		E	dorsolat	ca.mud	2	white	grey	mud.	—	✓	—
5355	Diictodon	"	9		D.	lat-up	nod.	2	cream	maroon grey	mud	—	✓	—
5356	Diictodon	"	9		E\F	dors-up / vent-up	nod.	4	white	grey maroon	mud.	—	✓	—

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CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5357	Diictodon	Dunedin	9	Tropid. Endo.	E		ca. lam nod.	4	cream	grey	mud	—	✓	—
5358	Diictodon	"	9		E	dors-up	nod	3	grey	grey maroon	mud	—	✓	—
5359	Dicynodont	"	9		E	dors-up	ca. lam	4	white	grey maroon	mud	105	✓	A
5360	Diictodon	"	9		E	ventro-lat	nod.	2	cream	grey maroon	mud	—	X	—
5361	Diictodon	"	9		E	lat-up	nod.	4	cream	grey maroon	mud	—	✓	—
5362	Diictodon	"	9		D	lat-up	none	2	cream	grey	mud	—	✓	—
5363	Diictodon	"	9		B	ventro-lat.	ca. lam.	1	white	grey maroon	mud	—	X	—
5364	Oudenodon	"	9		E	vent-up	nod.	4	cream	grey	mud	—	✓	—
5365	Dicynodont	"	9		E	lat-up	nod.	4	cream	grey green	mud	obsc.	obsc. ✓	—
5366	Oudenodon	"	9		F	lat-up	nod.	4	grey	grey	mud	—	—	—
5367	Diictodon	"	9		B	lat-up	nod.	2	cream	grey	mud	—	✓	—
5368	Diictodon	"	9		D	lat-up	ca. lam	4	grey	grey maroon	mud	—	✓	—
5369	Pristerodontid	"	7		D	dors-up	none	4	white	maroon	mud	—	obsc. ✓	—
5370	Diictodon	"	8		E	vent-up	nod	2	cream	green	silt	85	✓	A
5371	Dicynodont	"	8		?	?	none		white	grey	silt	—	—	—
5372	Pristerodont	"	8		E	vent-up	none	2	white	grey	silt	—	X	—
5373	Pristerodont	"	8		E	vent-up	nod	4	cream	grey maroon	mud	—	X	—
5374	Pristerodont.	"	8		D	vent-up	none	4	cream	maroon	mud	—	obsc. ✓	—

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TAPHONOMIC DATA SHEET FOR ..DUNEDIN................. STUDY BLOCK

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5375	? p.c. skeleton	Dunedin	8	Tropid./Endo	B	lat-up	ca. lam	2	cream	maroon brown	mud	—	—	—
5376	? small disass. skeleton	"	8		H			2		grey		—		—
5377	Dicynodont	"	8		E	dors-up	nod	4	white	green maroon	mud	—	X	—
5378	Dicynodonts (5)	"	8		E	2x dors-up 3x vent.	nod.	4	white cream	grey green maroon	mud	—	3x ✓ 1x x	—
5379	Pristerodont	"	8		E	vent-up	nod.	2	white cream	grey green maroon	mud	69	1x ✓ 1x x	A
5380	Dicynodont.	"	8		B	lat-up		4	cream	grey	mud	—		—
5381	Dicynodont	"	8		E	dors-up	nod.	5	cream	grey maroon	mud	—	X	—
5382	Gorgonopsian?	"	8		E	lat-up	ca. lam	4	cream brown	grey maroon	mud	—	✓	—
5383	Dicynodont	"	8		E	vent-up	none	4	cream	brown	mud	—	✓	—
5384	Dicynodont	"	8		E.	dors-up	nod	5	cream	maroon	mud	—	obsc ✓	—
5385	Diictodon	"	7		D	lat-up	nod	2	white	grey	mud	—	X	—
5386	Dicynodont	"	7		—	—	—	—	—	—	—	—	—	—
5387	Diictodon	"	5		E	dors-up	nod	2	yellow	grey	mud	—	✓	
5388	Diictodon	"	7		E	lat-up	ca. lam	4	cream yellow	grey	mud	—	X	—
5389	Dicynodont	"	7		D	vent-up	none	2	cream	green grey	silt.	62,5	obsc ✓	A
5390	Diictodon	"	7		D	lat-up	nod	2	cream purple crack fills	green	mud. ca. nod	—	✓	—
5391	Dicynodont	"	7		D	lat-up	none	2	cream	grey green	silt.	—	X	—
5392	Diictodon	"	7		D	ant/lat	nod	4	cream	grey	ca. nod	72	✓	A

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TAPHONOMIC DATA SHEET FOR DUNEDIN STUDY BLOCK

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5393	Diictodon	Dunedin	7	Tropid./Endo	D	lat-up	none	4	cream	grey	silt.	77,5	X	A
5394	Diictodon	"	7		E	dors-up	nod	2	cream	grey	mud	—	X	—
5395	Pristerodontid	"	7		D	vent-up	none	4	cream orange	grey	silt lam	—	X	—
5396	Oudenodon	"	7		E	dors. up	nod	2	white	grey green	mud	—	indet ✓	—
5397	Oudenodon	"	7		E	lat-up	nod	2	white	grey green	mud	-	✓	—
5398	Diictodon	"	7		E	lat-up	nod part	2	cream	green	silt	—	X	—
5399	Diictodon	"	7		E	ventro-lat.	ca mud	1	cream	grey green	mud	86	X	A
5400	? p-c pieces assoc. with K5399	"	7		B	—	nod	4	white	grey	—	—	✓(2x)	—
5401	Diictodon	"	7		D	dorso-lat	part nod.	2	brown	grey	mud	—	✓	—
5402	Diictodon	"	9		E	vent-up	none	2	white	grey	mud	91,5	✓	—
5403	Diictodon	"	9		E	dors-up	nod	2	white	grey maroon	mud	—	X	—
5404	Diictodon	"	9		B	lat-up	—	2	clean	grey maroon	mud	—	obsc ✓	—
5405	?	"	8		D	vent-up	nod	4	cream	grey green	mud	—	?	—
5406	Dicynodont	"	8		D	dors-up	nod	—	grey	grey	mud	—	—	—
5407	Dicynodont	"	8		D	dorso-pos-up	ca lam	2	cream	grey green	mud	—	✓	—
5408	Pristerodont.	"	9		E	dorso lat-up	none	4	white	grey green	mud	57	✓	A
5409	Scaloposaurid	"	9		E	dors-up	nod	—	grey	grey green	mud	indet.	X	—
5410	Diictodon	"	9		E/H	lat-up	ca.lam	4	cream	green	silt	—	✓	—

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CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5411	Pristerodont	Dunedin	9	Tropid/Endo	E	dors-up	ca.lam	2	grey	green	mud	—	X	—
5412	Pristerodont	"	9		D	lat-up	ca.lam	4	cream	grey maroon	mud	70	obsc ✓	A
5413	Dicynodont	"	9		D	lat-up	ca.lam	1	cream	grey green	mud	—	obsc ✓	—
5414	Pristerodont	"	9		E	vent-up	nod	5	orange	green	mud	indet	✓	—
5415	? p-cskeleton	"	9		G		ca lam	4	white	grey maroon	mud	—	—	—
5416	Diictodon	"	9		E	dors-up	nod	4	white	green maroon	mud	—	obsc ✓	—
5417	Diictodon	"	9		E	dors-up	—	2	grey	grey maroon	mud	—	✓	—
5418	Diictodon	"	9		E	lat-up	nod	4	cream	maroon	mud	—	X	—
5419	Diictodon	"	9		D	lat-up	nod	4	cream	grey maroon	mud	—	✓	—
5420	Diictodon	"	9		E	lat-up	ca lam	2	cream	maroon	mud	—	✓	—
5421	Dicynodont	"	9		E	pos-up vent-up	ca lam. nod.	4	cream	grey green maroon	mud	indet.	✓	—
5422	Oudenodon	"	9		F	dorso-ant-up	nod.	4	white pink	grey	mud	—	—	—
5423	Pristerodont	"	9		E	dors.-up	none	4	white	grey	mud	obsc	obsc ✓	—
5424	Dicynodont	"	7		—	—	—	—	—	—	—	—	—	—
5425	Dicynodont	"	7a		—	—	—	—	—	—	—	—	—	—
5426	? p-c parts	"	7		H	—	nod	4	cream	grey green	mud	—	—	—
5427	Pristerodont	"	7		D	lat-up	none	2	cream	grey green	mud	obsc	obsc ✓	—
5428	Pristerodontinid	"	7		D	vent-up	ca.lam.	4	cream	grey	mud	62	✓	A

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CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5429	Diictodon	Dunedin	7	Tropid./Endo	D	lat-up	nod	obsc.	obsc.	grey	mud	106	✓	A
5430	Pristerodont ind	"	7		E\H	dors-up	nod	4	cream grey	grey green	mud	indet	X	—
5431	Diictodon	"	7		E	dors-up	nod.	4	cream	grey green	mud	—	x	—
5432	Diictodon	"	7		E — D lat.-up F — D vent.-up		—	2	grey	green	mud	—	✓	—
5433	Diictodon	"	7		E	dors-up	—	5	white	grey green	mud	97	✓	A
5434	Diictodon	"	7		D	dors-up	ca. nod	4	white	green	mud	—	✓	—
5435	Dicynodont	"	7		E	dors-up	ca. lam	4	grey	grey green	mud	obsc	✓	—
5436	Emydops	"	7		D	lat-up	nod	4	white	grey	mud	obsc	X	—
5437	Diictodon	"	7		D	vent-up	nod	4	cream	green	mud	—	X	—
5438	? snout	"	7		E	vent-up	ca. lam	4	orange	grey	mud	—	✓	—
5439	Dicynodont	"	7		E	—	nod	obsc-2	white	grey	mud	—	X	—
5440	Diictodon	"	7		D	ventro lat.	nod	4	white	grey green	mud	—	✓	—
5441	? ass. p.c. parts	"	7		H	—	nod	4	grey	grey	mud	—	—	—
5442	? p.c. parts	"	7		H	lat-up	none	1	cream	grey green	mud	—	—	—
5443	Diictodon 2 snouts	"	7		E		ca. lam	4	white	grey	mud	—	X	—
5444	Diictodon + p.c. parts	"	7		B	vent-up	nod	obsc	cream	grey green	mud.	—	obsc	—
5445	Diictodon	"	7		A	—	—	—	—	—	—	—	✓	—
5446	Dicynodont	"	7		E	vent-up	nod	2	cream	grey green	mud	90	?	A

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CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5447	Diictodon	Dunedin	7	Tropid./Endo	E	lab-up	none	4	grey	grey	lam. mud.	87,5	✓	A
5448	? p.c. parts	"	7		H	—	nod.	4	orange/pink	grey green	mud	—	—	—
5449	Diictodon	"	7		E	lat-up	nod	2	white	grey green	mud	82,5	X	A
5450	Dicynodont	"	7		E\F\H	—	ca.lam.	2	white	grey green	mud.	—	indet	—
5451	Diictodon	"	7		E	vent-up	ca.lam	2	cream	grey green	mud	—	✓	—
5452	Diictodon	"	7		E\F	vent-up	ca.lam	4	cream	grey	mud	80	✓	A
5453	Diictodon	"	7		E	lat-up	ca.lam	4	cream	grey maroon	mud.	64	✓	A
5454	Dicyn.\Diic. cranial parts	"	4		E\F	—	nod	4	white cream	grey green	mud.	indet	✓	—
5455	Dicynodont	"	4a		E	dors-up	ca.lam	4	white	grey green	mud	51	X	A
5456	Oudenodon	"	4a		E	—	—	—	white	grey maroon	mud	—	—	—
5457	Dicynodont	"	4a		H	—	ca.lam	obsc.	obsc	grey	mud	—	—	—
5458	Diictodon	"	4a		E	1x dors-up 1x lat-up	nod	4	grey	grey maroon	mud	—	✓	—
5459	Pristerodontinid	"	4a		D	vent-up	ca.lam	obsc.	cream	grey maroon	mud.	76	obsc.	A
5460	? Diictodon	"	4a		D	dors-up	ca.lam.	4	grey	maroon	mud.	—	X	—
5461	Pristerodontinid	"	4a		E	dors-up	ca.lam	2	cream	maroon	mud.	73	X	A
5462	Diictodon	"	4a		2x E	vent-up	ca.lam	4	cream	grey maroon	mud	63,5	X	A.
5463	Pristerodontinid	"	4a		D	dors-up	nod.	4	white	grey green	mud	indet.	obsc ✓	—
5464	Dicynodont	"	4a		E	vent-up	nod.	5	white	obsc	—	indet.	X	—

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CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5465	Oudenodon	Dunedin	4a	Tropid. | Endo	D	dors-up	nod	3	cream	grey maroon	mud	—	X	—
5466	? p.c. parts	"	4a		G	—	none	2	grey	grey green	mud	—	—	—
5467	Diictodon	"	4a		E	dors-up	ca. lam	4	white	grey green maroon	mud	—	X	—
5468	Pristerodontinid	"	4		E	latro-post.	ca. lam	3	white	maroon	mud	—	obsc.	—
5469	Diictodon	"	4		E\H	lat-up	ca lam	4	cream	grey	silt.	—	✓	—
5470	? p.c. skull	"	4		H	—	ca. lam	4	cream	grey maroon	mud	—	—	—
5471	Dicynodont	"	4		D	lat-up	ca lam	obsc.	cream	grey green	—	—	obsc ✓	—
5472	Dicynodont	"	4		E\F	—	nod.	4	white	grey green	mud	—	✓	—
5473	Dicynodont	"	4		F	ant-up	ca. lam	4	white	grey green	mud	—	—	—
5474	? skull fragments	"	4		E	vent-up	ca. lam	4	cream	grey green maroon	mud.	—	X	—
5475	Dicynodont	"	4a		—	—	—	—	—	—	—	—	—	—
5476	Pristerodontinid	"	7		E	dors-up	none	2	cream orange	grey green	mud	obsc.	obsc	—
5477	Dicynodont	"	9											
5478	Diictodon	"	—		E	dors-up	nod	4	white	maroon	mud.	—	X	—
5479	Diictodon	"	—		E	vent-up	ca. lam	4	cream	grey maroon	mud	89	✓	A
5480	Dicynodont	"	9		E	—	ca. lam	1	cream	grey green	mud	—	X	—
5481	Dicynodont (several)	"	9		E\F.	—	nod	4	white cream	grey green	mud	—	✓ X 4	—
5482	Dicynodont PC PIECE	"	9		—	—	nod	1	cream	green maroon	mud	indet	indet ✓	—

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TAPHONOMIC DATA SHEET FOR ..DUNEDIN...................... STUDY BLOCK Page .22...... of ....

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE		TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5483	Dicynodont (frag. skulls)	Dunedin	9	Tropid.	Endo	E/F	dors-up	nod.	4	cream	grey green	mud	indet.	✓ 1x	—
5484	Dicynodont (partial skulls)	"	9			E	—	—	4	white	grey green	mud	—	obsc ✓	—
5485	Dicynodont	"	9			E	lat.-up	nod	4	grey	grey maroon	mud	—	✓	—
5486	Dicynodont (2)	"	9			E	1x dors. up / 1x vent. up	nod	4	white	1x grey / 1x green maroon	mud	—	✓	—
5487	Dicynodont	"	—			E	vent-up	nod.	4	white	maroon	mud	—	X	—
5488	Dicynodont (2 skulls)	"	8			E	1x dors-up / 1x vent-up	nod.	4	white	maroon	mud	indet	✓	—
5489	Dicynodont (3 snout + lower jaws)	"	8			E	1x dors. / 1x lab.	nod.	4	1x white / 1x cream / 1x pink	grey green	mud.	indet.	✓	—
5490	Dicynodont	"	8			E/F	latro. vent	nod	4	cream	grey green	mud	indet	✓	—
5491	Dicynodont (partial skull)	"	7			E	—	nod.	4	grey	grey green	mud	indet	3x ✓	—
5492	Dicynodont	"	7			B	lat.-up	ca lam	2	cream	grey green	mud.	—	—	—
5493	Dicynodont	"	7			E	vent-up	nod	2	cream	grey green	mud	indet	✓	—
5494	Pristerodontinid	"	7			E	vent-up	nod	4	white	green	mud	indet.	✓	—
5495	Dicynodont	"	7			D	lab-up	nod.	4	white	grey green	mud.	indet.	obsc ✓	—
5496	Dicynodont	"	7			D E H	[illegible]-up / [illegible] lat-up	nod.	4	white	green	mud	indet.	✓ x2	—
5497	Diictodon	"	7			E	vent-up	nod.	4	white	grey	mud	—	✓	—
5498	Oudenodon	"	7			E/F.	vent.-up	—	4	cream	grey	mud	—	obsc ✓	—
5499	Dicynodonts (loose snouts; occipits; pc. parts)	"	7a			3xD 19xE.	—	nod	4	cream	grey green	mud	—	✓ x16	—
5500	Pristerodontinid	"	7a			F	dors-up	ca. brn	4	grey	black brown	mud	—	—	—

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TAPHONOMIC DATA SHEET FOR ..DUNEDIN....................... STUDY BLOCK

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5843	Humerus - ? possibly Gorgon.	Dunedin	11	Tropid./Endo.	H	—	nod, encrust.	2	white cream	green	ca nod mud	192	—	A
5844	Diictodon	"	10		D	lat-up	nod	4	white, purple	grey green	silt ca nod	—	✓	—
5845	?Gorgonopsian (isolated humerus)	"	11		H	—	nod	1	cream	grey green mottled	silt ca nod/lam	—	—	—
5846	Diictodon	"	11		E	vent-up	nod.	4	cream brown	grey	mud	87	✓	A
5847	Diictodon	"	10		B	lat-up	part. nod	2	white purple crack fill.	grey green	mud. ca lam	95	✓	A
5848	Dicynodont	"	10		E	dors-up	nod	4	white	grey brown	ca nod	—	✓	—
5849	Dicynodont	"	10		B	lat-up	part. nod	—	white brown red.	grey	ca lam mud.	—	X	—
5850	Pristerodon (snout)	"	10		D	dors-up	nod.	2	white purple crack	grey	mud. ca nod	—	✓	—
5851	Diictodon	"	10		A	lat-up	nod.	2	cream	grey green	mud. ca lam/mud	indet	✓	—
5852	Pristerodon	"	10		E	dors-up	ca. lam	1	cream brown	grey	silty mud. ca. lam.	78	X	A
5853	Diictodon	"	10		D	lat-up	nod.	4	white purple	grey	ca. nod mud.	indet	✓	—
5854	Diictodon	"	15		E	dors-up	nod.	4	white purple crack.	grey	ca nod mud.	79,5	✓	A
5855	Diictodon	"	10		D	lat-up	nod.	3	white	maroon mottled	ca. nod	80	✓	A
5856	Dicynodont	"	10		D	dors-up	nod.	2	white purple crack	grey	ca. nod. breccia silt.	86	X	A
5857	Diictodon	"	11		E	dors-up	nod.	4	white	grey green	ca. nod. silt.	73	X	A
5858	Diictodon	"	13		D	lat-up	nod.	3	white red.	grey	silt	indet	✓	—
5859	Pristerodon	"	10		E	dors-up	nod	3	cream	grey	ca nod mud.	indet	X	—
5860	Diictodon	"	13		C	dors-up	nod.	1	white	grey	ca nod mud.	88	X	A

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TAPHONOMIC DATA SHEET FOR ...DUNEDIN..................... STUDY BLOCK

CAT. NO. SAM. K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5861	Diictodon	Dunedin	11	Tropid. / Endo	D	lat.-up	none	4	white brown	grey green	ca lam	63	✓	A
5862	Dicynodont	"	13		E	dors-up	none	1	white brown	grey green	mud	71	X	A
5863	Diictodon	"	10		C	lat.-up	nod.	3	white	grey	ca. nod. mud.	701	X	A
5864	Dicynodont	"	11		E	dors-up	none	2	grey brown	green maroon	silt.	61	?	A
5865	Pristerodon.	"	14		E	dors-up	none	3	white	grey green.	ca lam. mud.	74	X	A
5866	Dicynodont	"	10		D	dors-up	nod.	3	cream	maroon mottled	co mud ca. lam	indet	indet ✓	—
5867	Dicynodont	"	12		B	lat.-up	poss nod	2	white	grey	silt.	72	✓	A
5868	Dicynodont	"	14		E	dors-up ~~lat~~ -up	none	1	brown cream	grey green	silt.	indet	obsr	—
5869	Pristerodont indet	"	11		F	dors-up	none	4	white	grey	silt.	—	—	—
5870	Dicynodont.	"	14		D	lab-up	none	2	white brown(lt)	grey	mud	61	X	A
5871	Dicynodont	"	10		D	lat-up.	none	4	cream	grey	ca lam mud.	indet.	indet	—
5872	Dicynodont	"	10		D	lat.-up	nod.	2	white (purple)	—	ca.nod	—	✓	—
5873	Pristerodont	"	14		D	lat.-up	none	5	grey brown	green	silt	92.5	✓	A
5874	Pristerodont	"	14		D	indet	none	3	brown	grey green	ca.lam mud	indet.	X	—
5875	Dicynodont	"	14		E	lab.-up	none	1	brown	grey black.	ca.lam. mud	82	✓	A
5876	Pristerodon	"	13		F	dors-up	nod.	2	white	grey	ca. lam nod silt.	—	—	—
5877	Diictodon	"	14		E	vert-up	none	1	white cream	grey green	silty mud [ca lam]	7	—	I
5878	Oudenodon	"	11		E	lat.-up	nod.	4	white cream	grey black.	ca. nod. silt.	> 100mm indet.	✓	A

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TAPHONOMIC DATA SHEET FOR ...DUNEDIN..................... STUDY BLOCK

CAT. NO. SAM-K.	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5879	Pristerodon	Dunedin	13	Tropid/Endo	E	dors-up	none	1	grey brown	grey green	silty mud / ca lam	72,5	X ?	A
5880	Oudenodon	"	14		D ?	lat-up	nod ca lam	1	cream brown	grey	ca nod. mud	indet.	indet	—
5881	Oudenodon	"	14		E	vent-up	none	2	cream	grey green	ca nod silt.	164	X	A
5882	Diictodon	"	10		B	lat-up	nod.	4	(purple) white	grey green maroon/mottled	ca nod silt	97	X	A
5883	Diictodon	"	10		E	dors-up	nod.	4	grey brown (purple)	grey green	ca nod silt.	675	X	A
5884	Diictodon	"	10		D	indet	nod	3	purple replacemt.	green	ca nod. silt.	indet.	X	—
5885	Diictodon	"	11		E	vent-up	ca nod.	5	white	mottled	silt	indet.	X	—
5886	Diictodon	"	10		D	lat-up	nod.	4	red	grey green	silt.	94,5	✓	A
5887	Gorgonopsian	"	11		C ?	indet	nod.	1+2	white	green	silt ca nod	indet	—	—
5888	Diictodon scapula	"	10		H	—	calc. film.	5	cream purple clod fill	maroon	—	—	—	—
5889	Dicynodont	"	10		D	lat-up pos.-up	nod	1	cream	grey black	ca nod/lam mud	76	?	A
5890	Dicynodont	"	10		E	dors-up	nod.	4	white brown [illegible]	grey marm	ca nod/lam mud	indet	X	—
5891	Dicynodont	"	13		F	indet.	nod	3	white	grey green	silt.	indet.	—	—
5892	Dicynodont	"	10		C	lat-up	nod	2	brown	grey	ca lam silt.	71	✓	A
5893	Diictodon	"	10		C	lat-up	none	1	cream	grey green	ca lam mud	90	X	A
5894	Diictodon	"	10		E/F	dors-up	nod.	4	white grey	green maroon mottled	ca nod mud.	70,5	X	A
5895	Pristerodont	"	13		F/H	lat-up	none	2	white	grey	ca lam mud.	—	—	—
5896	Emydops	"	11		E	vent-up	nod.	[illegible]	cream	maroon	ca nod mud.	50	X	J

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TAPHONOMIC DATA SHEET FOR DUNEDIN STUDY BLOCK

CAT. NO.	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5897	Dicynodont	Dunedin	10	Tropid./Endo	B	—	none	1	white	grey	co.lam silt	indet	indet	—
5898	Pristerodon	"	10		C	lat-up	nod.	5	grey	green	silt	83	X	A
5899	Pristerodon	"	11		F	vent-up	nod.	2	white	grey green	silt.	—	—	—
5900	Diictodon	"	11		E	dors-up	none	4	white	grey green	mud	—	X	—
5901	Oudenodon	"	10		E	indet	none	4	brown	grey	mud	—	—	—
5902	Dicynodont	"	14		B\C	dors-up	nod.	3	white	green	co.lam mud.	45	✓	J
5903	Emydops	"	13		E	—	nod.	5	grey	green	co.lam silt	57	X	A
5904	Dicynodont	"	10		D	dors-up	nod.	3	white	green, grey maroon mottled.	silt mud co.nod.	80	X	A
5905	Dicynodont	"	11		E	lat-up	none	2	cream	grey green	silt	80	X	A
5906	Dicynodont	"	14		D	lat-up	nod.	5	white cream	green	silt co.nod	indet	✓	—
5907	Pristerodon	"	11											
5908	Pristerodon	"	13		E\F	vent-up	none	2	white	grey	mud	62	X	A
5909	Diictodon	"	13		C\D	lat-up	none	3	white	grey green	co.lam silt	75	X	A
5910	Diictodon	"	14		D	lat-up	nod.	1	white	grey black	co.lam mud.	68	✓	A
5911	Diictodon	"	10		E	dors-up	nod.	4	grey	grey	co.nod.	indet.	X	—
5912	Gorgonopsian	"	13		indet.	indet.	none	4	brown	grey green	silt	indet	indet	—
5913	Diictodon	"	11		D\E\F	lat-up	none	4	white cream	brown	co.lam mud	77	✓	A
5914	Diictodon	"	13		D	dors-up	co.silt.	indet	indet	grey green	co.lam silt.	99	✓	A

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TAPHONOMIC DATA SHEET FOR ....DUNEDIN.................... STUDY BLOCK Page .26..... of ....

CAT. NO.	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5897	Dicynodont	Dunedin	10	Tropid./Endo	B	—	none	1	white	grey	co.lam silt	indet	indet	—
5898	Pristerodon	"	10		C	lat-up	nod.	5	grey	green	silt	83	X	A
5899	Pristerodon	"	11		F	vent-up	nod.	2	white	grey green	silt.	—	—	—
5900	Diictodon	"	11		E	dors-up	none	4	white	grey green	mud	—	X	—
5901	Oudenodon	"	10		E	indet	none	4	brown	grey	mud.	—	—	—
5902	Dicynodont	"	14		B\C	dors-up	nod.	3	white	green	co.lam mud.	45	✓	J
5903	Emydops	"	13		E	—	nod.	5	grey	co.lam green	silt	57	X	A
5904	Dicynodont	"	10		D	dors-up	nod.	3	white	green, crcu maroon mottled.	silt mud co.nod.	80	X	A
5905	Dicynodont	"	11		E	lat-up	none	2	cream	grey green	silt	80	X	A
5906	Dicynodont	"	14		D	lat.-up	nod.	5	white cream	green	silt co.nod	indet	✓	—
5907	Pristerodon	"	11											
5908	Pristerodon	"	13		E\F	vent-up	none	2	white	grey	mud	62	X	A
5909	Diictodon	"	13		C\D	lat-up	none	3	white	grey green	co.bir silt	75	X	A
5910	Diictodon	"	14		D	lat-up	nod.	1	white	grey black	co.lam mud.	68	✓	A
5911	Diictodon	"	10		E	dors-up	nod.	4	grey	grey	co.nod.	indet.	X	—
5912	Gorgonopsian	"	13		indet.	indet	none	4	brown	grey green	silt	indet	indet	—
5913	Diictodon	"	11		D\E\F	lat-up	none	4	white cream	brown	co.lam mud	77	✓	A
5914	Diictodon	"	13		D	dors-up	co.silt.	indet	indet	grey green	co.lam silt.	99	✓	A

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TAPHONOMIC DATA SHEET FOR ..DUNEDIN.......................... STUDY BLOCK Page ..27...... of ....

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5915	Dicynodont	Dunedin	13	Tropid./Endo	E	dors-up	none	4	brown	grey	silt.	indet	✓	—
5916	Dicynodont	"	11		D	lat-up	slight nod.	4	white	grey green	mud.	65	indet	A
5917	Diictodon	"	10		C	lat.-up dors.-up	nod.	2	white grey	grey brown	ca.nod mud.	95	✓	A
5918	Diictodon	"	10		D	lat-up	nod.	4	white purple crack	grey\green), mottled	silt.	81	X	A
5919	Diictodon	"	11		D	lat-up	nod.	3	white	grey	silt ca nod	86	indet	A
5920	Dicynodont	"	11		E	vent-up	ca.mud	1	white	grey maroon	mud.	83	✓	A
5921	Dicynodont	"	14		E	dors-up	none	4	brown	grey green	silt	obsc.	indet	—
5922	Dicynodont	"	10		E → F →	vent.-up dors.-up	none	2	white	grey black	mud.	94	✓	A
5923	Dicynodont	"	11		B	dors-up	none	3	white	grey green	ca.lam silt	indet	indet*	—
5924	Dicynodont	"	11		D	lat.-up	nod.	—	white	maroon green	ca.lam ca nod	—	X	—
5925	Dicynodont	"	11		D	dors-up	ca.lam	2	white cream	grey green	ca.lam. mud.	60	X	A
5926	Dicynodont	"	11		indet	indet.	none	—	cream brown	grey maroon	mud.	—	—	—
5927	Dicynodont	"	11		D	lat-up	part. nod.	4	surface: grey\brown inside: white	maroon	ca.lam. mud.	indet.	✓	—
5928	Emydops	"	1		D	dors-up	—	2	cream	maroon	ca.lam. mud.	45	(incipient)	J
5929	Dicynodont	"	10		B	—	nod.	1	purple stain brown	grey brown	ca.nod mud.	—	—	—
5930	Diictodon	"	4		D	lat-up	none	1	cream	grey	silt	83	✓	A
5931	Pristerodon	"	10		E	dors-up	nod.	3	white (purple)	grey ca.lam.	ca.nod. silt.	indet	indet	—
5932	Diictodon	"	10		C	dors-up	nod.	4	white	maroon	ca.nod. mud.	75	✓	A

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TAPHONOMIC DATA SHEET FOR ....DUNEDIN.................... STUDY BLOCK

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5933	Dicynodont	Dunedin	4	Tropid. / Endo	A	—	—	specimen plastered	—	—	—	—	—	—
5934	Dicynodont	"	10		indet	lat-up	nod.	2	grey	grey	silt.	indet.	indet	—
5935	Dicynodont	"	10		D	indet.	nod.	4	cream purplecrack	brown	ca. nod.	indet.	✓	—
5936	Diictodon	"	13		D	lat.-up pos-up	nod.	3	grey	green	ca nod.	70	X	A
5937	Diictodon	"	1		B	lat-up	ca. lam.	1	white	grey	silt.	90	✓	A
5938	Diictodon	"	10		E	?ant-up	thin lam.	1	white	green brown	mud	obsc.	X	—
5939	Diictodon	"	10		D	lat-up	nod.	3	white	grey brown	ca. nod. mud.	?70 indet	indet	?
5940	Pristerodont\Diictodon	"	10		E x2	dors-up	nod.	4	grey	grey green	ca. nod. silt.	indet.	✓ Diict.	—
5941	Dicynodont	"	10		D	lat-up	nod. thin layer.	2+3	white	grey green	silt.	83	✓	A
5942	Dicynodont	"	10		D	lat-up	nod.	2+3	grey	brown	ca. nod.	indet.	X	—
5943	Diictodon	"	10		D	lat-up	nod.	3	white	grey	ca. nod silt.	indet.	X	—
5944	Dicynodont	"	11		D	lat-up	none	5	white	grey	silt.	—	X	—
5945	Diictodon	"	10		E	lat-up	none	2	white brown	grey	ca. lam. mud.	85	✓	A
5946	Dicynodont?	"	11											
5947	Oudenodon	"	10		F	indet	nod.	2	cream brown l. purple	grey	silt	—	—	—
5948	Oudenodon ?	"	10		?	lat-up	nod.	4	white cream brown\purple	grey	co. mud. mud.	—	—	—
5949	Dicynodont	"	10		D	lat-up	nod	4	white purple	grey green	ca. nod silt.	12	✓	I
5950	Diictodon	"	10		D	dors-up	nod.	2	cream brown	grey green	ca. lam mud.	81	✓	A

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TAPHONOMIC DATA SHEET FOR ....DUNSDIN.................... STUDY BLOCK

CAT. NO. SPM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5951	Diictodon	Dunsdin	15	Tropid./Endo.	D	lat-up	thin layer/ nod.	2	white	grey green	ca. lam. silt.	68	indet.	A
5952	Diictodon	"	10		D	dors-up	nod.	—	cream brown	grey maroon mottled	ca nod. silt.	96	✓	A
5953	Pristerodont	"	15		E	dors-up	not strongly dev. nod.	2	purple grey	grey green	ca. lam silt.	indet.	✓	—
5954	Diictodon	"	10		E\F	dors-up lat-up	part nod	2	white	grey	ca nod \lam mud.	84	X	A
5955	Pristerodon	"	10		D	dorso-lat-up	none	4	—	grey green	silt.	indet.	X	—
5956	Dicynodont	"	10		indet	indet.	ca. nod	2	(purple) white	grey	ca nod. mud.	—	X	—
5957	Dicynodont	"	10		indet	indet	nod.	4	(purple) cream.	green brown	ca. nod	indet.	indet.	—
5958	Diictodon	"	10		D	lat.-up	nod.	4	white	grey	silt.	±83	✓	A
5959	Diictodon	"	10		E	dors-up	nod.	4	white	grey brown	ca. nod silt.	855	X	A
5960	Oudenodon	"	10											
5961	Diictodon	"	11		E	lat.-up	nod.	4	white	green	ca nod. silt.	89	✓	A
5962	Diictodon	"	10		E	dors-up	nod.	4	white	grey	silt.	140	✓	A
5963	Oudenodon ?	"	11		E	dors-up	ca. mud.	4	white	maroon	ca nod. mud.	—	X	—
5964	Diictodon	"	10		C	lat.-up	encrusting lam.	4	cream	grey	ca. lam. mud.	92	X	A
5965	Dicynodont	"	10		B\D	lat-up	part. ca. nod	4	white cream	grey maroon mottled	mud.	90	✓	A
5966	Dicynodont	"	10		D	lat.-up	nod.	minutely 4	purple crack white	grey	ca. nod. silt.	82	✓	A
5967	Diictodon	"	11		B	lat-up	ca. lam.	4	white	grey green	mud.	±110	✓	A
5968	Dicynodont	"	7a		F	indet.	nod.	2	cream grey	green	mud.	—	—	—

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TAPHONOMIC DATA SHEET FOR ....DUNEDIN.................... STUDY BLOCK

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5969	Dicynodont	Dunedin	10	Tropid./Endo	B	lat-up	nod.	1	brown	brown	co. nod mud.	indet.	—	—
5970	Dicynodont	"	10		D	vent-up	nod.	4	cream brown	black	co. mud. mud.	—	indet.	—
5971	Dicynodont	"	10		C	dors-up lat-up	nod.	indet	white	grey	ca. lam. mud.	± 57	X ?	A
5972	Dicynodont	"	10		E	lat-up	ca lam	1	grey	grey	mud.	67	X	A
5973	Diictodon	"	10		B	lat-up	nod.	1	cream brown	green brown	co nod lam mud.	72,5	X	A
5974	Pristerodon	"	7a		E	pos-up	none	2+3	grey	grey	mud.	56,5	X	A
5975	Dicynodont	"	10		E	dors-up	nod.	4	red coat: white	brown	co nod.	—	indet.	—
5976	Pristerodon	"	7a		C	vent-up	nod.	4	white	grey	co. nod mud.	76,5	✓	A
5977	Diictodon	"	7a		E	dors-up	none	2	white	grey	mud.	65	X	A
5978	Diictodon	"	7a		E	ventro. ant-up	ca nod.	indet.	white cream	maroon	mud.	± 79	✓	A
5979	Diictodon	"	10		D	lat-up	part. nod.	2	cream brown purple	grey	silt.	80,5	✓	A
5980	Dicynodont	"	10		D	lat-up	nod.	4	white	grey	ca. nod. silt.	96	✓	A
5981	Diictodon	"	7a		B	dorso-lat-up	ca. nod.	2+3	cream	grey green	mud.	± 74	X	A
5982	Diictodon	"	10		E	dors-up	none	1	cream brown	black. grey	mud.	73	X	A
5983	Dicynodont	"	10		E	lat-up	ca. lam	2	white	grey	ca. lam. mud.	74	X	A
5984	Pristerodont	"	10		E	dors-up	none	2	cream brown	grey black.	mud.	87	✓	A
5985	Diictodon	"	10		D	dorso-lat-up	ca. lam	4	grey	grey black.	co. lam. mud.	indet.	X	—
5986	Diictodon	"	10		D	lat-up	nod.	2	white	grey	ca. lam. mud.	—	✓	—

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TAPHONOMIC DATA SHEET FOR ....DUNEDIN.................... STUDY BLOCK

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
5987	Diictodon	Dunedin	10	Tropid / Endo	D	indet	nod.	4	white brown	grey/green brown maroon	ca. mud	—	✓	—
5988	Pristerodon	"	7a		E?	lat.-up	nod.	4	grey	grey green	mud.	—	✓	—
5989	Pristerodon	"	10		D	lat-up	nod	4	white	grey	ca. lam. mud nod.	55	x	A
5990	Diictodon	"	10		D	dors-up	ca. lam	1	brown	maroon	silt. ca. lam	70	indet.	A
5991	Gorgonopsian	"	10		D	lat.-up	nod	4	white	grey green	ca. nod. silt.	—	—	—
5992	Dicynodont	"	7a		B	dors-up	nod	4	white	maroon brown	ca. nod	64	indet	A
5993	Dicynodont	"	10		A/B	lat-up	ca. lam.	4	white	grey brown	ca. mud mud.	91,5	✓	A
5994	Dicynodont	"	7a		D	dors-up	none	4	white	grey	ca. lam. silt.	80	✓	A
5995	Dicynodont	"	10											
5996	Diictodon	"	10		F	vent-up	ca. lam.	1	cream brown	grey	ca. lam. silt.	—	—	—
5997	Pristerodon	"	11		E	vent-up	nod.	4	white cream	green/maroon mottled.	ca. nod. silt	74	✓ (incipient)	A
5998	Dicynodont	"	10		C	lat.-up	none	4	cream	brown maroon	mud.	83	obsc.	A
5999	Dicynodont	"	11		D	dors-up	ca. mud.	2	white	grey	ca. lam. silt.	—	✓	—
6000	Gorgonopsian	"	13											
6001	Pristerodon	"	10		E	dors-up	nod.	1	cream	grey	silty mud. ca. lam	76	✓	A
6002	Diictodon	"	7a		E	ant-up	nod.	indet.	grey	grey	silt.	—	✓	—
6003	Diictodon	"	10		D	lat-up	none	2	grey brown	grey black	silt.	75	indet.	A
6004	Pristerodon	"	10		D	lat.-up	none	2	white	grey green	silt ca. lam.	indet.	✓	—

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TAPHONOMIC DATA SHEET FOR ....Dunedin.................................. STUDY BLOCK

CAT. NO. SAM-K.	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6005	Diictodon	Dunedin	10	Tropid./Endo.	E	lat.-up	nod.	4	white	grey	mudst. calc. nod.	indet.	x	—
6006	Dicynodont	"	4		D	indet	nod.	—	white	grey	siltst.	indet.	✓	—
6007	Pristerodon	"	10		B→E	lat.-up	none	2	white	maroon	mudst. calc. lam.	66.5	x	A
6008	Diictodon	"	10		D	lat.-up	none	2	brown greenish	grey	siltst. calc. lam.	72	✓	A
6009	Diictodon	"	10		D	lat.-up	nod.	—		grey	siltst. calc. nod.	95	✓	A
6010	Diictodon	"	10		I—	lat.-up	nod.	–	white	grey	mudst.	indet	x	—
6011	Dicynodont	"	4		B		nod.	1	cream	grey	siltst. calc. nod. calc. lam.	indet.	indet.	–
6012	Post crania indet.	"	10		B		nod.	3	white purple	green maroon mottled	calc. nod.	indet.	indet.	–
6013	Emydops	"	11		E	dorsal-up	nod.	4	white	grey	mudst. calc. nod. breccia	indet.	x	–
6014	Dicynodont	"	10		B	? lat.-up	nod.	1	brown	black maroon	mudst. calc. nod. calc. lam.	indet.	indet.	–
6015	Dicynodont	"	7a		D	lat.-up	none	2	white	grey black	mudst.	95	✓	A
6016	Dicynodont	"	10		D	vent.-up	nod.	1	brown cream	grey	siltst. calc. lam	obsc.	obsc.	–
6017	Diictodon	"	10		D	lat.-up	nod.	indet.	cream	grey	mudst. calc. nod. calc. lam.	90	indet	A
6018	Dicynodont	"	10		D	lat.-up	none	4	cream	grey	siltst.	obsc.	obsc.	—
6019	Dicynodont	"	7a		D, E	dorsal-up	nod.	—	cream grey	grey	siltst	obsc.	obsc	—
6020	Post crania assoc with K 6036	"	10		B		none	–	white	green	mudst. calc. lam	N/A	N/A	–
6021	Diictodon	"	11		E	dorsal-up	slight nod.	4	white	maroon	siltst.	74	x	A
6022	Pristerodon	"	11		D	dorsal-up	nod.	2	white brown	grey maroon mottled	mudst. calc. nod brecciated	indet.	x	–

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TAPHONOMIC DATA SHEET FOR ....Ounedin.................................... STUDY BLOCK Page ..33..... of ....

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6023	Dicynodont	Ounedin	10	Tropid. / Endo	E	lat.-up	none	2	cream brown	grey mottled	fine sst. mudstone chip breccia	± 89.5	×	A
6024	Pristerodon / Emydops	"	11		D	dorsal-up	none	1	cream	maroon	mudst. calc. lam.	indet	×	—
6025	Dicynodont	"	10		D	lat.-up	—	2	brown	grey	mudst.	± 90	✓	A
6026	Dicynodont	"	10		B	lat.-up	none	1	white cream	maroon	mudst. calc. lam.	indet	✓	—
6027	Indet skeleton	"	10		N/A	N/A	catamin	indet.	cream	grey	mudst. calc. lam.	—	—	—
6028	Dicynodont	"	11		D	dorsal-up	none	4	cream brown	grey green maroon	mudst calc. lam	indet	✓	—
6029	Dicynodont	"	11		indet.	dorsal-up	none	1	cream brown	green	siltst.	indet	indet.	—
6030	Diictodon	"	10		D	lat.-up	fissile calc. lam.	2	white brown	grey black	mudst. calc. lam.	indet	✓	—
6031	Diictodon	"	10		D	vent.-up	none	3		grey calcareous	silst.	79	×	A
6032	Dicynodont	"	10		A + B	lat.-up	partial calc. lam	4	cream brown	grey	mudst. calc. lam.	obsc.	obsc.	—
6033	Diictodon	"	11		D	dorsal-up	none	1	cream brown	maroon	mudst. calc. lam	88	✓	A
6034	Diictodon	"	10		E	dorsal-up	nod.	4	cream	grey maroon	mudst calc. nod. calc. lam.	65	×	A
6035	Oudenodon	"	13		E	dorsal-up	none	2	white cream	grey	mudst.	—	×	—
6036	Pristerodon	"	10		A + B	lat.-up	nod.	1	white	grey maroon	mudst. calc. nod breccia	indet.	✓	—
6037	Pristerodon	"	11		E	dorsal-up	none	4	white	grey	siltst. calc lam	83	×	A
6038	Dicynodont	"	13		indet.	lat.-up	calc. sst.	—	purple red	grey green	siltst.	—	—	—
6039	Dicynodont	"	13		D	lat.-up	nod	4	white	grey	mudst. calc. lam.	66.5	×	A

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TAPHONOMIC DATA SHEET FOR ....Dunedin.............................. STUDY BLOCK

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CAT. NO. SAM - K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6077	Diictodon	Dunedin	4	Tropid./Endo	D	lat.-up	nod.	4	white	maroon	mudst calc. nod. calc. lam	61	x	A
6078	Diictodon	"	4		O	lat.-up	nod	4	white	grey green	calc. nod	–	x	–
↓														
6079	Emydops	"	4		E	dorsal. up	nod.		purple	grey	siltst.	42	x	J
6080	Emydops ?	"	4		C	lat.-up	calamin calc. mudst	1	cream	grey	silty. mudst calc. lam.	45	✓	J
6081	Pristerodon	"	4		F	indet.	nod.	4	white	grey	siltst.	–	–	–
6082	Diictodon	"	4		O	lat.-up	calc. mudst	4	white	grey	mudst.	86	✓	A
6083	Pristerodon	"	4a											
6084	Oudenodon ?	"	7a.											
6085	Pristerodon	Dunedin	4		O	lat.-up	calc. sst.	4	brown	maroon	siltst.	52	✓	A
6086	Diictodon	"	4a		O	dorsal, lat.-up	nod.	4	white	grey	siltst.	–	x	–
6087	Dicynodont	"	4		E	indet.	nod.	indet.	white	brown	calc. nod	–	–	–
6088	Diictodon	"	4		E	lat-up	nod.	3	white	grey brown	mudst. calc. nod	66	✓	A
6089	Diictodon	"	4		O	lat.-up	calamin	2	brown	grey black	mudst. calc. lam	–	✓	–
6090	Diictodon	"	4		O	lat.-up	nod	5	white	brown	calc. nod	62	✓	A.
6091	Dicynodont	"	4		O	lat.-up	nod.	5	white	green	mudst.	–	✓	–
6092	Pristerodon	"	4		O	lat -up	none	5	white	black	mudst	–	✓	–
6093	Diictodon	"	4		O	lat-up	nod.	4	grey white	grey green	mudst calc. nod.	–	x	–

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TAPHONOMIC DATA SHEET FOR ....Dunedin.............................. STUDY.BLOCK Page ...35.... of ....

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6094	Pisterodon	Dunedin	4	Tropid / Endo	D	lat. - up	Nod.	3	white	grey	mudst.	–	x	–
6095	Dicynodont	"	4		D	lat. - up	Nod.	3	white	grey	mudst.	75	indet.	A
6096	Pristerodontid	"	4a		E, F	dorsal - up	Nod.	4	white	grey green	siltst.	–	indet.	–
6097	Diictodon	"	4		D	lat. - up	Nod.	4	white	grey	siltst.	± 90	✓	A
6098	Diictodon	"	10		D	lat. - up	catamin. nod.	3	cream yellow	grey green	mudst.	–	3 ✓ 2x	–
6099	Oudenodon	"	4		E	dorsal - up	nod.	2	white brown	grey green	siltst.	–	x	–
6100	Diictodon	"	4		E	dorsal - up	nod.	4	white	grey green	mudst. calc. nod. breccia	–	x	–
6101	Diictodon	"	5		D	dorsal - up	calc. mudst.	2		grey	mudst.	93	✓	A
6102	Dicynodont	"	5		D	lat. - up	none	2	white cream	grey green mottled	siltst.	–	–	–
6103	Pristerodon	"	4		D	vent - up	calc. slst.	4	white	grey	siltst. calc. lam	77	indet	A
6104	Diictodon	"	4		D	dorsal - up	none	4		grey green	mudst.	71	x	A
6105	Oudenodon	"	7a		E	indet.	none	4	cream yellow reddish brown	grey green	siltst.	–	x	–
6106	Diictodon	"	5		E	lat. - up	nod.	2	white	grey green	mudst.	–	x	–
6107	Pisterodon	"	4		D	indet.	nod.	3	white	grey brown maroon	mudst. calc. nod.	–	x	–
6108	Dicynodon	"	5		B + D	lat. - up	nod catamin.	4	white	green	mudst. calc. lam.	–	x	–
6109	Dicynodon	"	4		E	dorsal - up	nod.	4	white	grey	mudst. calc. nod	–	x	–
6110	Diictodon	"	4		D	lat. - up	catamin calc. mudst.	4	white red	grey green	mudst. calc. lam.	–	✓	–
6111	Dicynodon	"	4		indet.		none	1	white brown	grey	mudst.	–	–	–

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TAPHONOMIC DATA SHEET FOR ....Dunedin.............................. STUDY BLOCK Page ..36..... of ....

CAT. NO. SAM - K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6112	Indet.	Dunedin	4	Tropid./Endo.	B		nod.	4		grey	siltst. calc. lam.	–	–	–
6113	Diictodon / Dicynodon	"	4		F	vent.-up	nod.	4	white grey	grey green	mudst. calc. lam.	–	–	–
6114	Pristerodon	"	4		E	dorsal, lat.-up	nod.	2	white	grey green	siltst. calc. nod.	–	×	–
6115	Dicynodon	"	5		B	dorsal-up	none	1	white	green	mudst.	–	–	–
6116	Diictodon	"	5		E	dorsal-up	nod.	4	white cream	grey	mudst.	–	✓	–
6117	Dicynodon	"	4a		D	lat.-up	nod.	4	white	green	mudst. calc. nod.	–	×	–
6118	Pristerodon	"	5		E	vent.-up	nod.	3	white	indet.	calc. nod.	77	✓	A
6119	Pristerodon.	"	4											
6120	Dicynodon	"	7a		H		none	2	cream brown	grey maroon	mudst.	–	–	–
6121	Dicynodont	"	4		D	lat.-up	nod.	4	white	grey green	siltst.	–	×	–
6122	Dicynodont	"	5		E	vent.-up	none	3	white	grey green	mudst.	80	obsc.	A
6123	Diictodon		7a		B	dorsal-up	catamin	1	cream	grey	siltst. calc. lam.	78.5	×	A
6124	Diictodon	"	4		E	dorsal-up	nod	2	white brown	grey green mottled	mudst. calc. nod. calc. lam.	81	×	A
6125	Diictodon	"	5		E	dorsal-up	none	2	white	grey green	siltst.	–	×	–
6126	Diictodon	"	5		D	dorsal-up	catamin	4	cream brown	grey green	siltst.	–	✓	–
6127	Diictodon	"	7a		D	vent.-up	nod.	2	white	grey	siltst.	80.5	×	A
6128	Diictodon	"	4		D	lat.-up	nod.	4	white	green	mudst. calc. lam.	± 98	✓	A
6129	Diictodon	"	4		E	lat.-up	none	1	white	green	mudst.	80	×	A

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TAPHONOMIC DATA SHEET FOR Dunedin STUDY BLOCK

CAT. NO. SAM - K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6130	Dicynodon	Dunedin	4	Tropid./Endo	D	lat. up	nod	4	white	grey brown	calc. nod.	–	x	–
6377	Oudenodon ?	"	4		B		nod	1	white	green	siltst.	–	–	–
6378	Diictodon	"	7		D	vent. - up	none	4	white	grey green	siltst.	–	–	–
6379	Diictodon	"	4a		E	lat. - up	none	1	white	grey	mudst.	–	–	–
6380	Diictodon	"	17		E	dorsal - up	none		grey	grey green	mudst.			
6381	Dicynodon? / Emydops?		17		D	lat. - up								
6382	Pisterodon	"	4a		D	dorsal - up	none	4	white	grey maroon mottled	mudst.			
6383	Diictodon	"	4a		D	lat. - up	none	1	white	grey green	siltst.			
6384	Dicynodon	"	4a		D	dorsal - up	none	2	grey	grey black	mudst.			
6385	Diictodon??	"	7		E	dorsal - up	nod.	4	cream	grey	siltst.			
6386	Diictodon	"	17		D	lat. - up	calcmin		white	grey	mudst.			
6387	Oudenodon	"	17		D	vent. - up	nod.	2	cream	green	calc. nod.			
6388	Diictodon	"	4a		E	vent. - up.	none	2	white	grey black	mudst.			
6389	Diictodon	"	17		D	lat. - up	calcmin		white	grey green	calc. nod.			
6390	Dicynodon	"		Aula./Cist.			calcmin			green maroon mottled	siltst.			
6391	Oudenodon	"	21	Tropid./Endo	D	dorsal - up								
6392	Dicynodon	"			C					grey	siltst.			
6393	Oudenodon	"	21		B	lat. - up								

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I = Infant J = Juvenile A = Adult

TAPHONOMIC DATA SHEET FOR Dunedin STUDY BLOCK Page 38 of ....

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6394	Diictodon	Dunedin	7	Tropid./Endo.	D	dorsal-up	nod.	4	grey	brown	calc. nod.			
6395	Dicynodon	"	4a		G			1	white	grey	siltst.			
6396	Diictodon	"	4a		E	dorsal-up	none	2	white	grey	mudst.			
6397	Emydops / Diictodon	"	4		D		none	1	white	green	siltst.			
6398	Diictodon	"	17		E	vent.-up	nod.	2	white	green	calc. nod.			
6399	Dicynodont	"	4a		D	lat.-up	none	4		grey	siltst.	–	✓	–
6400	Diictodon	"	4		D	lat.-up	none	2	white cream	grey	mudst.			
6401	Diictodon	"	4		E	dorsal-up	none	1	cream	grey green	siltst.			
6402	Dicynodon	"	7		D	lat.-up	nod.		white	grey green	siltst.			
6403	Diictodon	"	7		D	dorsal, lat.-up	nod.	2	white	brown	calc. nod.			
6404	Diictodon	"	17		E	lat.-up	none	2		grey	mudst.	–	×	–
6405	Diictodon	"	4a		D		nod.	1	grey	brown	mudst.	–	✓	–
6406	Endothiodont	"	18											
6407	Therocephalian	"	17		F									
6408	Dicynodont	"	18		E	dorsal-up	nod.	1		black	siltst.			
6409	Pristerodon	"	17		D			2						
6410	Diictodon	"	4a		B	lat.-up	none	1	white	brown	mudst.			
6411	Diictodon	"	7.1		E	dorsal-up	none	1	white	grey green	siltst.			

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TAPHONOMIC DATA SHEET FOR ......Dunedin...... STUDY BLOCK

CAT. NO. SAM. k	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6412	Diictodon	Dunedin	4a	Tropid./Endo	D	lat.-up	none	4	white	grey green	mudst.	–	×	–
6413	Therocephalian	"	17				none	4	grey	grey	siltst.			
6414	Dicynodont	"	4		D	lat.-up	none	1	cream	grey	mudst.	–	✓	–
6415	Gorgonops torvus?	"	17		D	lat.-up	nod.		red	grey	siltst.			
6416	Diictodon	"	7			dorsal, lateral-up	nod.	2	white	green brown	siltst. calc.nod.	–	✓	–
6417	Gorgonopsian	"	7		D	lat.-up	none	2	white	grey green	siltst.	–	–	–
6418	Pristerodon?	"	17		E	dorsal-up	nod		white	grey	siltst.	–	–	–
6419	Oudenodon	"	49		E	dors-up	none	1	cream	grey	mud	–	–	–
6420	Pristerodon hind	"												
6421	Diictodon	"	17		E	vent-up	none	–	cream	green	silt	–	–	–
6422	Diictodon	"	7		D	lat-up	–	4	white	grey green	mud	–	–	–
6423	3 theroceph fragments	"	7		–	–	nod	–	–	–	–	–	–	–
6424	Oudenodon	"	20		D	ant-up	none	1	grey	green	mud.	–	–	–
6425	Pristerodon?	"	4a		E	dors-up	none	4	–	grey	mud	–	–	–
6426	Diictodon	"	4a		D	vent-up	ca.nod	4	white	green	ca.nod	–	–	–
6427	Diictodon	"			D	lat-up	–	3	–	grey maroon mottled	silt	–	×	–
6428	Diictodon	"	19	Aula./Cist.	–	–	–	–	–	–	–	–	–	–
6429	Pristerodon?	"	21	Tropid./Endo	D	dors-up	–	–	–	grey	silt.	–	–	–

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TAPHONOMIC DATA SHEET FOR DUNEDIN STUDY BLOCK Page 40 of ....

CAT. NO. SAM K.	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6430	Diictodon skull	Dunedin	1	Tropid./Endo	E	lat-up	—	—	—	grey	mud	—	✓	—
6431	Diictodon skull	"	19	Aula./Cist.	D	lat-up	none	—	—	green	silt.	—	—	—
6432	Oudenodon snout	"	19	"	—	—	none	—	—	maroon	mud	—	—	—
6433	Diictodon	"	4a	Tropid./Endo	D	lat-up	none	—	white	green grey	mud	—	—	—
6434	snout Endothiodont	"	1		E	dors-up	nod	—	—	grey	ca.nod silt	—	—	—
6435	Dicynodont	"	21		D	lat-up	nod,mat	—	—	grey	silt	—	X	—
6436	Pristerodon	"	4a		D	dors-up	none	4	cream	grey	silt.	—	—	—
6437	Diictodon.	"												
6438	Diictodon	"	19	Aula./Cist	E	vent-up	—	—	—	grey	silt	—	—	—
6439	Dicynodont	"	1	Tropid./Endo.	E	dors-up	—	—	—	—	—	—	—	—
6440	Diictodon	Rosedene		Aula./Cist	E	dors-up	nod	—	—	—	—	—	—	—
6441	Oudenodon	"	22	"	E	vent-up	nod	—	—	—	—	—	—	—
6442	Diictodon	Dunedin	1	Tropid./Endo		—	—	—	—	brown	ca.nod	—	—	—
6443	Dicynodont (med)	"	19	Aula./Cist.	D	dors-up	ca.nod breccia	—	—	maroon mottled	silt	—	✓	—
6444	Diictodon	"	1	Tropid./Endo	E	dors-up	ca.nod. mat.	—	—	brown	ca.nod	—	—	—
6445	Diictodon	"	4a		E	vent-up	none	4	white	grey green	silt.	—	X	—
6446	Endothiodon	"	17		E	lat-up	nod	1	red	grey	mud	—	—	—
6447	Gorgonopsian	"												

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TAPHONOMIC DATA SHEET FOR ....DUNEDIN.................. STUDY BLOCK　　　　Page ..41...... of ....

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6608	Diïctodon	Dunedin	L8	Tropid./Endo.	C	dors-up	none	2	cream	greenish grey	silt	72	X	A
6609	Diïctodon	"	L8		D	lat-up	none	2	white	grey green	silt/ fine sst.	86	✓	A
6610	Diïctodon	"	L8		E	dors-up	nod.	2	cream	grey green	ca. nod	64	X	A
6611	Diïctodon	"	L8		D	dors-up	part. nod.	4	white	grey maroon mottled	silt	73	X	A
6612	Pareiasuchus peringueyi	"	L8		D	dors-up	none	—	cream	grey	fine sst.	250	—	A
6613	Diïctodon	"	L17		D	vent-up	ca. nod	—	cream brown	grey maroon mottled	ca. nod. silt.	87	✓	A
6614	Diïctodon	"	L17		E	lat-up	ca. lam	2	cream	v. dark brown	silt.	72	X	A
6615	Diïctodon	"	L17		D	lat-up	nod. mat	4	white	grey	ca. nod	83	✓	A
6616	Pristerodon	"	L17		E	dors-up	part. nod.	2	brown	grey	silt.	59	✓	A
6617	Diïctodon	"	L17		D	lat-up	ca. lam	2	white	grey	silt	112	✓	A
6618	Endothiodon	"	L17		B	lat-up	ca. lam	2	red. maroon	grey	silt	—	✓	—
6619	Diïctodon	"	L22	Aula./Cist.	A	dors-up	none	1	white	grey	fine sst.	± 98	?	A
6620	Diïctodon	"	L24	Tropid./Endo.	D	lat-up	+ nod. ca. lam.	1	cream	v. dark grey	silt.	90	✓	A
6621	Diïctodon	"	L24		C	lat-up	nod. mat. ca. lam.	4	cream	grey	silt	80	X	A
6622	Diïctodon sp.	"	L24		D	vent-up	ca. lam nod. mat	2	cream	grey green	ca. nod. silt.	66	X	A
6623	Emydops	"	L24		D	vent-up	part. nod.	2	white	grey green	silt.	53	X	A
6624	Diïctodon	"	L24		D	dors-up	none	1	cream brown	grey green	fine sst.	83.5	✓	A
6625	Diïctodon	"	L24		D	dors-up lat-up	ca. lam	1	cream brown	grey v. dark brown mottled	silt.	85	✓	A

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TAPHONOMIC DATA SHEET FOR ..DUNEDIN.................................. STUDY BLOCK

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6626	Diictodon	Dunedin	L24	Tropid./Endo	D	lat-up	some ca. impr. silt + ca. lam	1	white	dark grey	silt	82	✓	A
6627	Pristerodon	"	L24		E	dors-up	co. nod + ca. lam	4	white	dk grey green	silt co. nod	69	✗	A
6628	Diictodon	"	L24		E	vent.-up	nod + mudst.	4	white	dark grey	ca. nod	130	✓	A
6629	Pristerodon	"	L24		E	dors-up	ca. lam	2	white	grey	fine sst	75	✓	A
6630	Diictodon	"	L24		D	lat-up	none	4	white	green	fine sst.	86	✗	A
6631	Diictodon	"	L24		C	lat-up	nod. mat skull only	4	cream	d. grey	silt.	82	✓	A
6632	Diictodon	"	L24		D	lat-up	ca. lam.	4	white	grey	silt.	107	✓	A
6633	Gorgonops sp	"	L24		D	lat.-up	ca nod brec. silt	4	white grey	brown	silt. co. nod.	—	—	—
6634	Diictodon	"	L4		A	dors-up pos-up	some nod. mat.	—	white	grey green	fine sst.	83	✓	A
6635	Pristerodon indet?	"	L4		F	dors-up	① nod + ca lam. ② none.	?	white	grey	silt	—	—	—
6636	Diictodon	"	L4		E	lat-up	none	2	white	green	mud.	±83	✓	A
6637	Diictodon	"	L4		D	lat-up	closed in ca. nod.	4	white	brown	silt	61	✗	A
6638	Pristerodon	"	L23		D	lat-up		2	cream yellowish brown	dk. grey	silt.	±80	✓	A
6639	Diictodon	"	L25		E	vent-up	ca. lam + nod.	?	white	grey	silt.	77	✗	A
6640	Diictodon	"	L25		D	vent-up	ca nod.	?	white	grey green	silt	96	✓	A
6641	Pristerodon	"	25(a)		E	dors-up	ca. lam	4	white	v. dk. grey	silt.	80	?	A
6642	Cistecephalus	"	25(a)		E	dors-up	ca. nod	2	white	grey green	silt.	±43	✓	J
6643	Gorgonopsian	"	L25(a)		A\B		ca. lam	2	white cream	grey brown	silt.	—	—	—

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TAPHONOMIC DATA SHEET FOR DUNEDIN STUDY BLOCK

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
7049	Emydops	Dunedin	L1.	Tropid/Endo										J
7050	Pristerodon	"	L1											
7051	Emydops	"	L1											
7052	Diictodon	"	L1											
7053	Diictodon	"	L1.											

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TAPHONOMIC DATA SHEET FOR ....REIERSVLEI.................... STUDY BLOCK

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6557	Diictodon	am. boom	L1	Tropid./Endo	D	dors-up	ca. lam	4	cream	grey maroon	silt	90	✓	A
6558	Diictodon	"	L1		D	lat-up	ca. lam	2	white	grey green	silt	88.5	–	A
6559	Pristerodontia?	"	L1		D	pos-up	none	2	cream	brown	fine sst	96	–	A
6560	Diictodon	"	L1		D	lat-up	ca. layer	2	white grey	grey green	fine sst	94	X	A
6561	Dicynodont	"	L1		D	vent-up	none	2	grey	brown	fine sst	100	–	A
6562	Diictodon	"	L1		D	vent-up	–	2	cream	grey green	fine sst.	91	–	A
6563	Dicynodont	"	L1		D	dors-up	ca. lam	3	white grey	grey green	fine sst	13	X	I
6564	Tropidostoma	"	L1		E	dors-up	–	4	yellowish cream	grey	fine sst	130	X	A
6565	Diictodon	"	L1		C	ant.-up vent-up	nod.	4	cream	grey	silt	117	X	A
6566	Dicynodont	"	L1		E	vent-up	ca. lam	4	white cream	grey green	fine sst.	51	–	A
6567	Diictodon	"	L1		D	dors-up	none	4	cream grey	grey maroon	mud	70	X	A
6568	Tropidostoma	"	L1			lat-up		4	yellow cream	maroon	mud	99.5	1 X ✓	A
6569	Diictodon	"	L1			ant-up	none	4	cream grey	brown	silt	56	–	A
6570	Diictodon	"	L1		D	lat-up		4	grey	grey green	silt	102.5	✓	A
6571	Tropidostoma	"	L1			ant-up	ca. lam	3	white	grey	fine sst	–	✓	–
6572	Diictodon	"	L1		D/G	dors-up	ca. lam	4	cream	grey	mud	81	–	A
6573	Diictodon	"	L2		E	lat-up	none	3	white grey	grey	silt	112	–	A
6574	Diictodon	"	L2		snout	–	calc layer	2	cream	grey	silt	–	–	–

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TAPHONOMIC DATA SHEET FOR ....REIERSVLEI................ STUDY BLOCK

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6575	Diictodon	am. boom	L2	Tropid. / Endo	C	lat-up	calc layer	2	white grey	grey brown	silt	80	1X✓	A
6576	Diictodon	"	L2		E	lat-up	calc layer	4	cream	grey black	fine sst.	82	–	A
6577	Dicynodont	"	L2		D	lat-up	none	3	cream	grey	silt	87	X	A
6578	Dicynodont	"	L2		D	vent-up	none	4	white grey	grey brown	silt.	140	X	A

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TAPHONOMIC DATA SHEET FOR ....REIERSVLEI.................. STUDY BLOCK

CAT. NO. SAM E	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6703	Pristerodon \ Emydops	am. boom	L8	Tropid./Endo	D	lat.-up	ca. lam.	(1)	grey	grey	silt.	51	X	A
6704	Diictodon	"	L8		B	lat-up	ca. lam	1	light grey	grey	silt	119	✓	A
6705	Diictodon	"	L8		C	dors-up	ca. lam + nod. mat	2	grey brown	grey green	silt	114	✓	A
6706	Diictodon	"	L8		D	vent-up	ca. lam	1	cream brown	grey green	silt.	85	?	A
6707	Diictodon	"	L8	Aula/Cist.	C	lat-up	nod	2	white cream	grey	ca. nod	105	✓	A
6708	Ictidosuchoides	"	L8		D	lat-up	none	2	cream	grey green	fine sst	—	—	—
6709	Diictodon	"	L8		D	lat-up	nod.	4	white	grey	silt	72	X	A
6710	Pristerodon	"	L8		E	dors-up	none	4	cream	brown maroon	silt.	77	X	A
6711	Pristerodon	"	L8		C	dors-up	ca. lam	2	white cream	grey brown	silt	69	✓	A
6712	Diictodon	"	L8		E	vent-up lat-up	ca. lam	?	?	dk. grey	silt.	79	✓	A
6713	Oudenodon	"	L8		?									
6714	Pristerodon	"	L8		F	dors-up	none	2	cream	grey brown	silt	—	—	—
6715	Gorgonopsian	"	L8		D	lat-up	none	4	grey brown yellow	grey brown	silt	—	—	—
6716	Diictodon	"	L8		B	dors-up	ca. lam.	(1)	grey	grey green	silt	135	✓	A
6717	Diictodon	"	L8		B	dors-up	ca. lam	1	cream brown	dk. grey	silt.	113	✓	A
6718	Diictodon	"	L6	Tropid./Endo	E	vent-up	nod. mat	?	cream	dk. brown	calc. silt.	± 72	X	A
6719	Diictodon	"	L6		E	lat-up	nod. mat	(1)	grey brown	dk. brown	silt.	85	✓	A
6720	Diictodon	"	L6		E	dors-up	nod. + ca. lam.	?	?	dk. grey	silt.	81	X	A

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TAPHONOMIC DATA SHEET FOR ....REIERSVLEI.................. STUDY BLOCK

CAT. NO. SAM K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6721	Pristerodon	Am. boom	L6	Tropid/Endo	D	vent-up	ca.lam	4	cream	grey brown	silt	70	✓	A
6722	Emydops	"	L6		D	dors-up lat-up pos-up	nod ca.lam.	2	grey brown	dk. red brown	silt	63	X	A
6723	Therocephalian	"	L6		?	?	none	—	dk. brown black		silt	—	—	—
6724	Diictodon	"	L6		D	lat-up	ca.nod	4	cream grey brown	red brown	silt ca.nod.	105	—	A
6725	Diictodon	"	L6		D	lat-up	ca.lam	4	brown	dk. red brown	silt	84	X	A
6726	Diictodon	"	L6		D	lat-up	nod	—	cream brown	red brown	silt	92,5	X	A
6727	Endothiodon	"	L6		?	?	?	?	cream	?	?	?	?	?
6728	Rhinesuchus	"	L6		B	dors-up	nod	—	cream	green	silt	?	—	?
6729	Diictodon	"	L6		A	dors-up	ca.lam nod	4	cream brown	brown	silt	77	?	A
6730	Diictodon	"	L5		A	lat-up	none	(1)	white	dk red brown [illegible]	silt	97	✓	A
6731	Ictidosuchoides	"	L5		D	lat-up	nod	1	brown	dk. brown	silt	96	—	A
6732	Eunotosaurid	"	L5		G		none				silt			
6733	Diictodon	"	L1		E	dors-up	ca.lam	1	cream brown	dk. brown	silt	81	✓	A
6734	Emydops	"	L2		D	dors-up	nod					35	X	J
6735	Emydops	"	L2		D	?	nod		cream brown			36	X	J
6736	Diictodon	"	L2		D	lat-up	nod	4		dk. gray	silt	126	✓	A
6737	Diictodon	"	L2		D	pos.-up dors-up	nod	2	cream	grey green	silt	—	✓	—
6738	Diictodon	"	L2		D	dors-up	ca.nod + lam	2	cream	grey brown	silt	78	?	A

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TAPHONOMIC DATA SHEET FOR ....REIERSVLEI.................... STUDY BLOCK

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6738	Diictodon	Am. boom	L2	Tropid./Endo	D	dors-up	ca nod + lam	2	cream	grey brown	silt	78	?	A
6739	Diictodon	"	L2		D	lat-up	none some ca lam	1	cream brown	grey black	silt	116	✓	A
6740	Diictodon	"	L2		D	lat-up	nod.	4		grey	silt	103	X	A
6741	Diictodon	"	L2		C	dors-up	complete nod.					98	✓	A
6742	Tropidostoma	"	L2		E	dors-up	none	1	cream	brown	silt	230	✓	A
6743	N/A													
6744	Oudenodon 'baini'	"	L3		E	dors-up	ca. nod.	2	grey	brown	calc. nod.	?	X	—
6745	Emydops	"	L3		D	dors-up	ca. lam	—	grey brown	grey green	silt.	57	X	A
6746	Diictodon	"	L3		D	lat-up dors-up	ca. bm	2	brown	grey	silt.	64	X	A
6747	Gorgonopsian	"	L3		E	lat-up	calc. sst.	—	brown	brown	fine sst.	—	—	—
6748	Diictodon	"	L3		D	lat-up	none	—	brown	brown maroon	silt	90	✓	A
6749	Diictodon	"	L3		D	lat-up	calc. lam	4	light grey	grey brown	silt	98	✓	A
6750	Pristerodon	"	L3		E	dors-up lat-up	calc. lam	2	white cream	grey green	silt	79	X	A
6751	Ictidosuchoides	"	L3		E	dors-up	ca lam	2	brown	grey brown	silt	—	—	—
6752	Diictodon	"	L3		E	lat-up	none	2			silt	96	X	A
6753	Dicynodont	"	L3			dors-up	Ca. lam.	2	cream	brown maroon	silt	90	✓	A

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I = Infant J = Juvenile A = Adult

TAPHONOMIC DATA SHEET FOR ....REIERSVLEI.................... STUDY BLOCK

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6852	Dicynodon	am'boom	L9	Prist./Diict.	E	?	nod. co. sst.	4	cream	grey	fine sst	100	✓	A
6853	Diictodon	"	L9		C	dors-up	ca. silt	2	cream	grey green	silt.	79	✓	A
6854	Dicynodont?	"	L9		H	—	ca. sst.	4	white	green	fine sst	—	—	—
6855	Diictodon	"	L9		C	lat-up	ca. lam	1	cream	grey	silt.	83	✓	A
6856	Ictidosuchoides	"	L9		E	?	none	2	grey	grey	silt	?	—	—
6857	Diictodon	"	L9		D	lat-up	ca. silt ca. lam	2	cream brown	grey	silt.	79	✓	A
6858	Diictodon	"	L9		D	lat-up	calc. nod	4	brown	grey green	silt calc. nod.	84,5	✓	A
6859	Dicynodont	Ryersvalley	L10		D	lat-up	nod.	4	cream brown	grey green	silt.	?	×	—
6860	Pristerodon	"	L6	Tropid/Endo	D	?	ca. silt	—	brown	grey maroon	silt	70	✓	A
6861	Pristerodon	"	L6		D	dorso lat-up	nod.	2	brown	grey green	silt ca. nod.	60	✓	A
6862	Emydops	"	L6		E	dors-up	nod.	2	cream brown	grey	silt calc nod	59	×	A
6863	Diictodon	"	L6		D	?	nod.	2	cream	grey brown	silt. calc. nod	—	×	—
6864	Pristerodon	"	L6		C	dors-up	ca. silt.	2	cream	brown	silt	68	✓	A
6865	Diictodon	"	L6		D	lat-up	ca. silt.	2	cream	grey brown	silt	95	✓	A
6866	Diictodon	Brandewyns Gat Bergvallei 214	L12	Prist./Diict	E	dors-up	ca. lam	1	black	grey	fine sst.	—	×	—
6867	amphibian	Bergvallei	L13	Tropid./Endo	?	?	ca. silt	—	gold	grey green	siltic calc.	—	—	—
6868	Diictodon	Reiersvlei 401 (am'boom)	L11		D	lat-up	ca. lam	4	grey	grey green	fine sst	113,5	×	A
6869	Diictodon	Brandewyn's Gat Waterval 214	L14		D	lat-up	nod.	4	white	green	silt.	103,5	✓	A

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TAPHONOMIC DATA SHEET FOR ...REIERSVLEI................. STUDY BLOCK Page ..50.... of ....

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6870	Dicynodont.	Waterval	L14	Tropid/Endo	D	vent-up	ca. silt	4	white	maroon	silt.	—	?	—
6871	Diictodon	"	L14		D	dors-up	ca. nod.	4	white	grey	silt	102	X	A
6872	Diictodon	"	L14		D	lat-up	ca. nod	4	white	green	silt.	79	X	A
6873	Diictodon	"	L14		D	lat-up	nod.	4	white	grey green	silt.	102	X	A
6874	Diictodon	"	L14		D	lat-up	ca. silt.	4	white	grey green	silt.	82	X	A
6875	Diictodon	"	L14		D	lat-up	ca. silt.	2	white	grey green	silt.	75	X	A
6876	Pristerodontid	"	L14		D	lat-up	none	2	white	black.	silt.	52	X	A
6877	Dicynodont	"	L14		E	vent-up	ca. silt.	1	white	green	silt.	34.5	X	J
6878	Diictodon	"	L14		D	lat-up	ca. lam	2	cream	grey black.	silt.	40	X	J
6879	Dicynodont (med.)	"	L14		D	lat-up	ca. silt	4	white	grey black.	silt.	—	X	—
6880	Diictodon	"	L14		D	lat-up	ca. silt.	4	white	grey green	silt.	86	X	A
6881	Diictodon	"	L14		E	lat-up	ca. silt.	4	white	grey brown	silt.	80	X	A
6882	Dicynodon sp.	"	L14		D	?	ca. silt nod.	4	white	grey black maroon	silt.	—	—	—
6883	Gorgonopsian	"	L14		?	?	ca. rich silt.	4	white	green	silt.	—	—	—
6884	Gorgonopsian	Ryers Valley 481 \ am. Boom	L11		E	ventro-lat-up	ca lam	—	cream	grey	—	—	—	—
6885	anomodont (indet.)	Reiersvlei	L6		C	dors-up	ca. nod.	4	white	maroon	mud. calc nod	47	—	J
6886	Ictidosuchoides	"	L10	Prist./Diict	C	dors-up	ca. lam.	2	brown	grey brown	silt.	132	—	A

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TAPHONOMIC DATA SHEET FOR ....REIERSVLEI.................... STUDY BLOCK

CAT. NO. SBMK.	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6932	Dicynodont	Waterval	L15	Tropid./Endo	D	pos-up	nod.	—	—	grey	silt	124	✓	A
6933	Dicynodont	"	L15		C	lat-up	ca nod ca.lam	—	brown	grey	silt	111	✓	A
6934	Diictodon	"	L15		D	lat. ant-up	some nod.	2	grey brown	grey	fine sst	98	✓	A
6935	Diictodon	"	L15		D	lat-up	ca.nod	—	grey	grey green	fine sst	61	—	A
6936	Emydops	"	L15		E	dors-up	ca.nod.	2	grey	brown	fine sst	59	X	A
6937	Dicynodont	"	L15		—	—	Nod + lam. mat.	—	brown	grey green	silt	—	—	—
6938	Pristerodontinid	"	L16	Prist./Diict.	D	dors up	ca.lam	4	cream	brown	silt	80	✓	A
6939	Ictidosuchus	"	L17											
6940	Tropidostoma?	"	L11	Tropid./Endo	E	dors-up	nod	—	brown	grey	silt	122	✓	A
6941	Diictodon	"	L11		A	dors-up	calc. nod.	2	grey	grey	silt	100	✓	A
6942	Emydops	"	L11		E	dors-up	ca.lam	—	brown	grey	silt	65	X	A
6943	Diictodon	"	L18		D	lat-up	nod	—	cream	grey	silt	98	X	A
6944	Diictodon	"	L18		D	lat-up	nod	4	white	maroon	clay-pellet conglomerate pos burrow fill	88	✓	A
6945	Diictodon	"	L18		E	lat-up	nod.	4	cream	brown	silt	87	X	A
6946	Oudenodon	"	L14		D	lat-up	some ca. lam	2	cream	green	silt	168	X	A
6947	Pristerodon	"	L14		E	dors-up	some ca.lam	2	cream	grey brown	silt	79	X	A
6948	Diictodon	"	L14		D	dors-up	nod	—	cream	grey green	fine sst	64	X	A
6949	Diictodon	"	L14		D	lat-up	ca.lam	4	cream	brown	silt	—	X	—

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TAPHONOMIC DATA SHEET FOR ...REIERSVLEI........................ STUDY BLOCK Page ..52... of ....

CAT. NO. SAM K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6950	Diictodon	Waterval	L14	Tropid/Endo	D	lat-up	nod	2	white	green brown mottled	fine sst.	77	–	A
6951	Pristerodon	"	L14	|	C	vent-up	some ca lam	4	white	green brown	silt.	60	X	A
6952	Diictodon	"	L14	|	D	dors-up	nod.	–	white	green	fine sst	63	–	A
6953	Dicynodont	Reiersvlei	L6	|	C	lat-up	nod.	4	white cream	grey green maroon	fine sst.	97	✓	A
6954	Pristerodon	"	L6	|	D	vent-up	ca.lam.	–	cream	brown	silt.	77	✓	A
6955	Diictodon	"	L6	|	E	lat-up	none	1	brown	grey	silt.	74	–	A
6976	Diictodon	Waterval		Prist/Diict	A	lat-up	nod.	2	cream	brown	silt	125	✓	A
7005	Endothiodon	Reiershvai		Tropid/Endo	B/E	–	nod	4	brown	green maroon	silt	–	–	–

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TAPHONOMIC DATA SHEET FOR ....TEEKLOOF.................... STUDY BLOCK

CAT. NO. SAM K.	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6754	Diictodon	Wilbadene	L11	Tropid./Endo	D	lat-up	—	(1)	brown	grey	silt	120	✓	A
6755	Diictodon	"	L11		D	dors-up	none	2	black	grey green	fine sst.	73	✓	A
6756	Oudenodon	"	L11		E	dors-up	calc. nod.	2	grey	grey green	silt.	134	X	A
6757	Diictodon	"	L11		D	lat-up	ca. lam.	2	brown	grey	silt	89	X	A
6758	Dicynodont	"	L11		B?	vent-up	ca. lam.	?	cream	grey		?	✓	—
6759	Pristerodon	"	L11		E	vent-up	ca. lam. ca. silt.	2	white cream	grey maroon	silt	99	X	A
6760	Dicynodont	"	L11		D	lat-up	ca. nod	4	cream	brown maroon	ca. nod. silt.	112	✓	A
6761	Diictodon	"	L11		E	vent-up	ca. lam	2	brown	grey	silt.	725	✓	A
6762	Diictodon	"	L11		D	dors-up	ca. lam	4	cream	grey green	silt	84	X	A
6763	Diictodon	Teekloof	L10		D	lat-up	ca. lam [illegible]	2	white	grey	ca. nod. silt.	80	X	A
6764	Dicynodont	"	L10		E	dors-up	ca. lam	2	black	grey green	silt.	43	—	J
6765	Diictodon	"	L10		D	lat-up	ca. lam	—	black	grey	fine sst	79	✓	A
6766	Diictodon	"	L10		D	dors-up	calc. nod.	4	white	grey brown maroon	silt. ca. nod.	80	✓	A
6767	Diictodon	"	L10		D	dors-up	ca. lam	2	cream	grey brown	silt.	98	✓	A
6768	Diictodon	"	L10		C	dors-up	calc. sst ca. lam	2	brown	grey green	fine sst.	108	✓	A
6769	Diictodon	"	L10		D	lat-up	ca. silt ca. lam.	—	black	grey brown	calc. silt.	88	✓	A
6770	Diictodon	"	L10		E	vent-up	ca. lam	2	cream	green maroon	fine sst. silt.	72	✓	A
6771	Diictodon	"	L10		D	lat-up	ca. lam	2	white	grey green	silt	90	✓	A

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TAPHONOMIC DATA SHEET FOR TEEKLOOF STUDY BLOCK

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6772	Diictodon	Teekloof	L10	Tropid./Endo	D	lat-up	ca. lam.	2	grey	grey green	fine sst.	92	✓	A
6773	Diictodon	"	L10		D/E	lat-up	ca. lam	1	black	grey green	silt	78	X	A
6774	Diictodon	"	L10		D	lat-up	none	—	grey	grey brown	silt	82	X	A
6775	Diictodon	"	L10		E	dors-up	none	2	black	grey black	silt.	72	X	A
6776	Diictodon	"	"		C	lat-up	ca. lam	4	cream	grey green	fine sst	91	✓	A
6777	Diictodon	"	L10		D	dors-up	ca. lam. nod. [illegible]	(1)	white cream	grey green	silt.	89	✓	A
6778	Diictodon	"			C	dors-up	ca. rich silt.	2	grey	grey green		90	✓	A
6779	Emydops	Willowdene	L3		C	pos-up	ca. lam.	1	black	grey	silt.	49	X	J
6780	Pristerodon	Beauro 238	L3		B/C/b	dors-up	calc. nod.	4	cream	grey brown	calc. nod.	74	X	A
6781	Diictodon	"	L3		B	lat-up	none	—	brown	grey	fine sst silt	79	✓	A
6782	Diictodon	"	L5		A	ant.-up	ca. lam.	1	cream brown	grey green	fine sst.	97	✓	A
6783	Diictodon	"	L5		D	dors-up	ca. lam	2	cream	grey green	fine sst	110	X	A
6784	Diictodon	"	L5		C	lat-up	ca. silt. ca. lam	2	brown	grey brown mottled	silt	103	X	A
6785	Diictodon	"	L5		C	lat-up	ca. silt. ca. lam+nod	4	white cream	grey green	silt	85	X	A
6786	Diictodon	"	L5		D	lat-up	ca. lam.	—	grey	grey green	silt	74	X	A
6787	Diictodon	"	L5		C	lat-up	ca. lam	4				64	X	A
6788	Diictodon	"	L5		D	lat-up	ca. silt	4	grey	green	silt.	87	X	A
6789	Diictodon	"	L5		E	dors-up	nod.	2	cream brown	grey	silt.	100	✓	A

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TAPHONOMIC DATA SHEET FOR ....TEEKLOOF.................. STUDY BLOCK

CAT. NO. SAM-K-	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6790	Pristerodon	Willowdene Beaufort 238	L5	Tropid. / Endo	B	vent-up	ca. lam	2	white	grey	silt	96	X	A
6791	Diictodon	"	L5		E	lat-up	Ca. lam	2	cream	grey	silt.	90	X	A
6792	Pristerodon	"	L5		C/D	dorso-pos-up	ca. lam	—	cream grey	grey brown	silt	89	X	A
6793	Diictodon	"	L5		D	lat-up	ca. nod.	2	brown	grey green	fine sst.	83	X	A
6794	Diictodon	"	L5		E	pos-up	co. lam	2	grey	grey brown	silt.	—	X	—
6795	Tropidostoma	"	L5		E	vent-up	none	2	cream brown	grey green	silt.	—	✓	—
6796	Oudenodon	"	L5		E	dors-up	co. lam + nod.	4	white	grey green brown	silt	112	X	A
6797	Oudenodon	"	L5		E	dors-up	ca. lam ca. silt	2	brown	grey green	silt	159	X	A
6798	Diictodon	"	L5			vent-up	ca. lam	—	cream	green	silt	83	✓	A
6799	Diictodon	"	L5		D	lat-up	ca. lam	2	white grey	grey green brown	silt.	82	X	A
6800	Oudenodon	"	L5		E	vent-up	ca. lam	3	brown	grey	silt	155	X	A
6801	Diictodon	"	L5		E	vent.-up	ca. lam	2	cream brown	grey green	fine sst.	91	✓	A
6802	Gorgonopsian	"	L5		E	dors-up	ca. lam	4	grey	grey	silt	—	—	—
6803	Diictodon	"	L5		E	lat-up	none	2	cream	grey green	mud	62,5	—	A
6804	Diictodon	"	L5		E	vent-up	ca. lam	2	white	grey green	silt.	58	X	A
6805	Diictodon	"	L5		D	lat-up	—	4	brown	brown	mud.	74	X	A
6806	Diictodon	"	L5		E	vent-up	irreg. nod. + co. lam	4	cream	grey brown	ca. nod silt.	89	X	A
6807	Diictodon	"	L5		D	lat-up		2	grey	grey green	mud	69	X	A

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TAPHONOMIC DATA SHEET FOR ....TEEKLOOF.................... STUDY BLOCK

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6808	Oudenodon	Willowdene Beaufort 238	L5	Tropid./Endo.	E	dors-up	nod.	2	grey	grey	silt.	—	X	—
6816	Diictodon	"	L5		E	lat-up	ca. silt	4	cream	grey green	silt	112	✓	A
6817	Diictodon	Matjiesfontein	L8		D	dors-up	ca. lam	2	brown	grey brown	silt	120	✓	A
6818	Dicynodon	" 235.	L8		D	vent-up	ca. sst	2	brown	grey green	fine sst	123.5	✓	A
6819	Diictodon	"	L8		D	vent-up	ca. lam	2	white	grey brown	silt.	75	X	A
6820	Diictodon	"	L8		D	lat-up	—	2	brown	grey	silt	96	X	A
6821	Diictodon	Beaufort 238	L7		B	lat-up	ca. nod mat.	—	grey	grey	silt	110.5	✓	A
6822	Diictodon	Willowdene "	L7		C	lat-up	ca. nod.	?	grey	grey green	—	127	✓	A
6823	Emydops	"	L7		D	vent-up	ca. silt ca. lam	2	cream	grey green	silt.	46	✓	J
6824	Pristerodon	"	L7		C	dors-up	ca. nod.	4	white grey	brown maroon	silt.	52.5	✓	A
6825	Pristerodon	"	L7		E	dors-up	ca. lam	1	cream	grey	silt	86	X	A
6826	Dicynodont	"	L7		D	lat-up	ca. silt	2	white	grey green	silt	52	—	A
6827	Diictodon	"	L7		D	lat-up	ca. nod.	4	white	grey green	—	78	X	A
6828	Dicynodont	Achterplaats	L4		D	lat-up	ca. nod	2	grey	grey	silt	113	✓	A
6829	Diictodon	" 438	L4		E	ventro-lat-up	ca. lam ca. silt	4	white	grey, brown maroon mottled	silt	85	X	A
6830	Dicynodont	"	L4		D	lat-up	ca. sand.	2	brown	grey green	fine sst. mud.	110	✓	A
6831	Dicynodon	"	L4		C	lat-up	ca. silt. ca. lam.	2	white	grey brown maroon	silt.	87		A
6832	Diictodon	"	L4		E	lat-up	ca. nod ca. lam	4	white	grey green	silt. ca. nod.	70	X	A

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TAPHONOMIC DATA SHEET FOR ....TEEKLOOF.................... STUDY BLOCK

CAT. NO. SAM-K	IDENTIFICATION	FARM & NO.	FIELD LOCAL	BIOZONE	TAPHO. CLASS	ATTITUDE OF SKULL	PERIMIN. TYPE	WEATH. STAGE	COLOUR OF BONE	COLOUR OF MATRIX	LITH. OF MATRIX	SKULL LENGTH (mm)	TUSK	MATURITY
6833	Emydops	Matjesfontein 235	L4	Tropid./Endo	D	dors-up	ca. lam	2	brown	grey	silt.	94	X	A
6834	Oudenodon	Wilgerbosdrift "	L4		E	vent-up	none	2	brown	grey brown	silt	158	X	A
6835	Lycaenops	"	L4		D	lat-up	ca. lam	2	grey black.	Light grey	fine sst.	—		—
6836	Diictodon	Ouberg Pass 438	L9		D	dorso-lat-up	ca. burr ca. sst.	4	brown black	green	fine sst.	78	?	A
6837	Pristerodon	"	L9		E	dors-up	ca. nod ca. lam	4	white	grey green	silt.	71,5	X	A
6838	Diictodon	"	L9		D	dors-up	ca. sst ca. lam.	2	black	grey green	fine, sst	114	✓	A
6839	Diictodon	"	L9		D	lat.-up	ca. lam.	2	grey brown	grey	silts	76	X	A
6840	Diictodon	"	L9		C	lat-up	ca. lam.	2	dk. brown	grey green	silt	75	✓	A
6841	Oudenodon	Groot Tafelberg fontein 237	L6		E	dors-up	ca. nod	2	white	grey	silt	152	X	A
6842	Diictodon	"	L6		D	lat-up	ca. lam.	2	white	grey green	silt.	96	X	A
6843	Ictidosuchoides	"	L6		D	?	none	4	white	green	fine sst	?		—
6844	Diictodon (2)	"	L6		A	ant-up	ca. lam.	1	white	grey green	siltst.	95 107	1X ✓ 1X X	A
6845	Diictodon	"	L6		E	dors-up	ca. nod	2	white	grey green	silt	87	X	A
6846	Diictodon	"	L6		D	lat-up	ca. nod.	4	white	grey green	silt calc nod.	53	X	A
6847	Emydops	"	L6		D	dors-up	ca. lam.	2	cream	grey black.	mud	32	X	J
6848	Diictodon	"	L6		D	lat-up	ca. lam	—	brown	grey green maroon mottled	silt.	96,5	✓	A
6849	Oudenodon	"	L6		E	vent-up	ca. silt	—	white grey	grey	silt.	—	X	—
6850	Pristerodon	"	L6		E	? loose	calc. nod.	4	cream	green	fine sst. calc. nod.	106	X	A

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GSO = GEOLOGICAL SURVEY OF SOUTH AFRICA, PRETORIA

I = Infant J = Juvenile A = Adult

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6851	Oudenodon	Groot 237 Kaffelkeinfont.	1 6	Tropid/Endo	E	ventro pos-up	Ca.lam	4	cream brown	grey	silt	—	?	—
6956	Dictodon	Teekloof		Tropid/Endo	C	lat-up	Ca lam	–	brown	grey	f.sst.	95	✓	A
6957	Diictodon	" Pass			D	dorso lat-up	Calam	–	–	grey	silt	65	–	A
6958	Diictodon	"			E	dorso lat-up	Ca lam	1	brown	grey	silt	89	X	A
6959	Diictodon	"			D	lat-up	Ca lam	1	brown	grey	silt	77	X	A
6960	Emydops	"			E	dors-up	Ca lam	1	brown	grey	silt	60	X	A

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