7. PALAEOGEOGRAPHY, GRAVEL DEPOSITION AND ORIGIN OF DIAMONDS

7.1 Palaeogeography and gravel deposition

Sedimentation of the diamondiferous gravel runs of Bakerville was greatly influenced by the karst topography of the underlying dolomite basement. Erosion and karstification of the dolomitic bedrock was evidently well advanced prior to the onset of deposition of the oldest gravels which are of Tertiary age according to Du Toit (1951). Features formed during four recognised periods of karstification (Martini and Kavelieris, 1976) were predominantly structurally controlled.

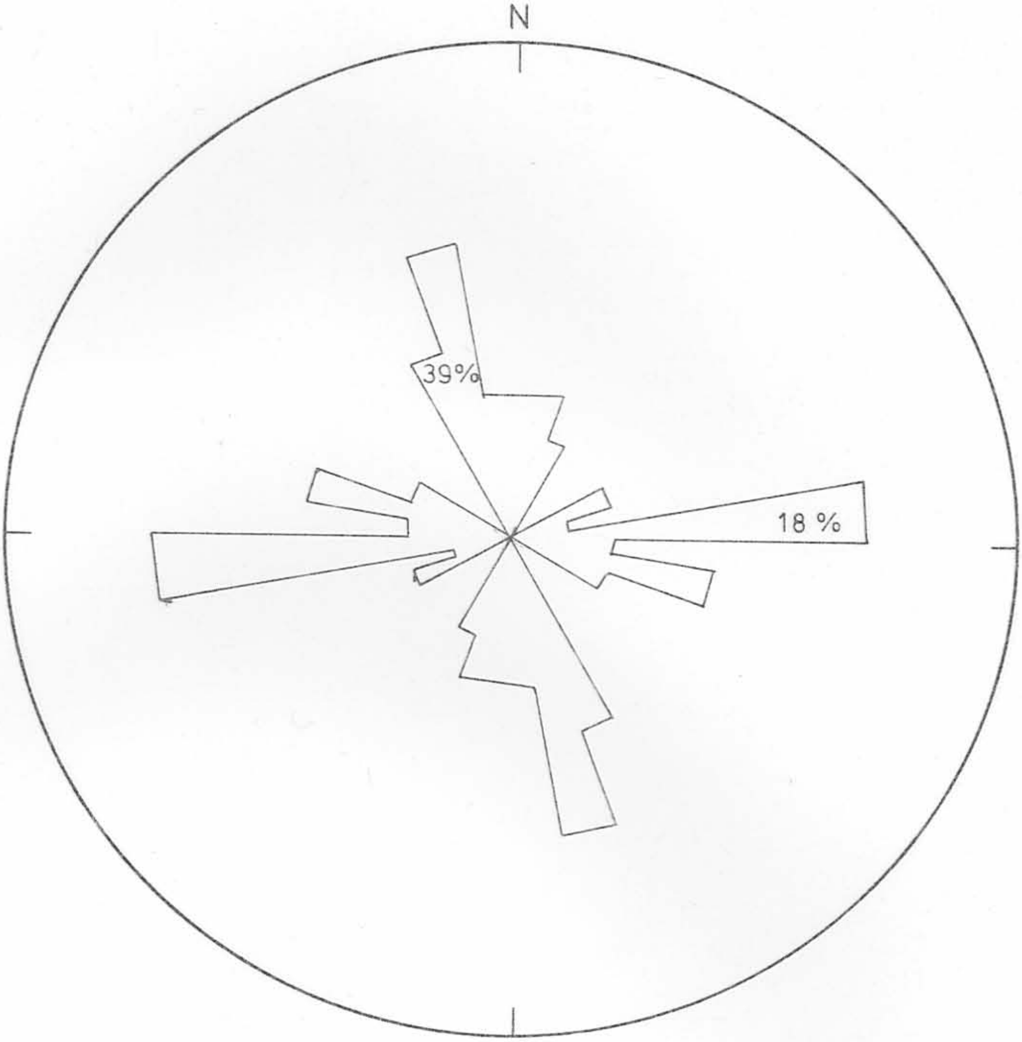
Jointing is the only macroscopic manifestation of tectonism on the dolomites. Bedding is nearly horizontal and faulting of any kind is rarely observed. Two major joint directions, one just west of north (350°) and the other just north of east (080°), are evident (fig. 26). These directions are comparable on a regional scale with the two major structural trends of the Archaean complex as discussed by Wilson (1977).

There is a significant coincidence between the joint orientation and that of the dykes and quartz veins (figs. 27 and 28) (Day, 1980), suggesting preferential intrusion along these planes of structural weakness although the quartz veins are only found in the northerly trend. Similarly, a statistical concurrence between the orientation of the dykes and joints, and that of the gravel runs and the gravity anomalies (figs. 26, 27, 29 and 30) indicates a causal connection.

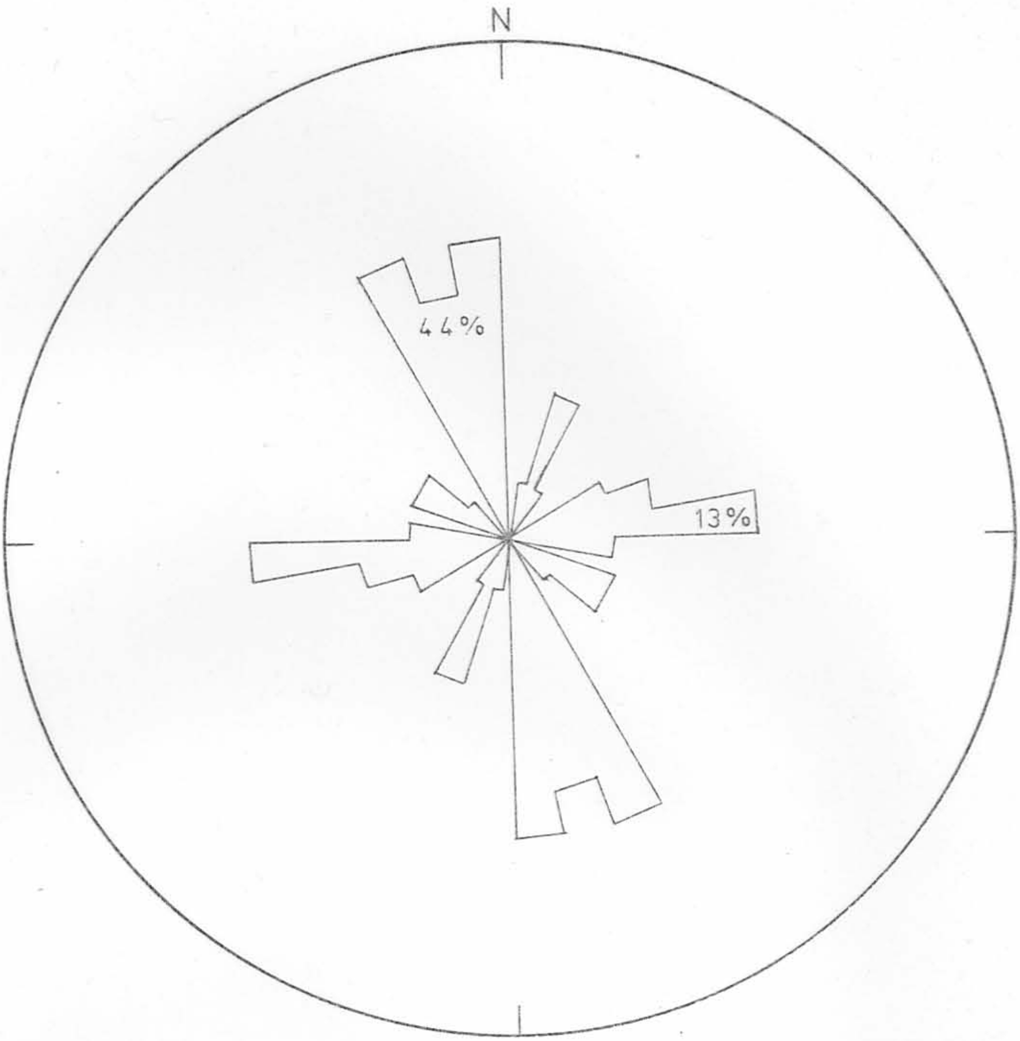
The long axes of the King's and Malan's potholes are also aligned along these main regional joint trends.

The development of caves in the Bakerville area by dissolution at joint planes followed a two stage process involving (1) the random formation of wall pockets (cavities) through differential solution of the dolomite and (2) the collapse of pocket partitions through further chemical and mechanical erosion causing cavity coalescence.

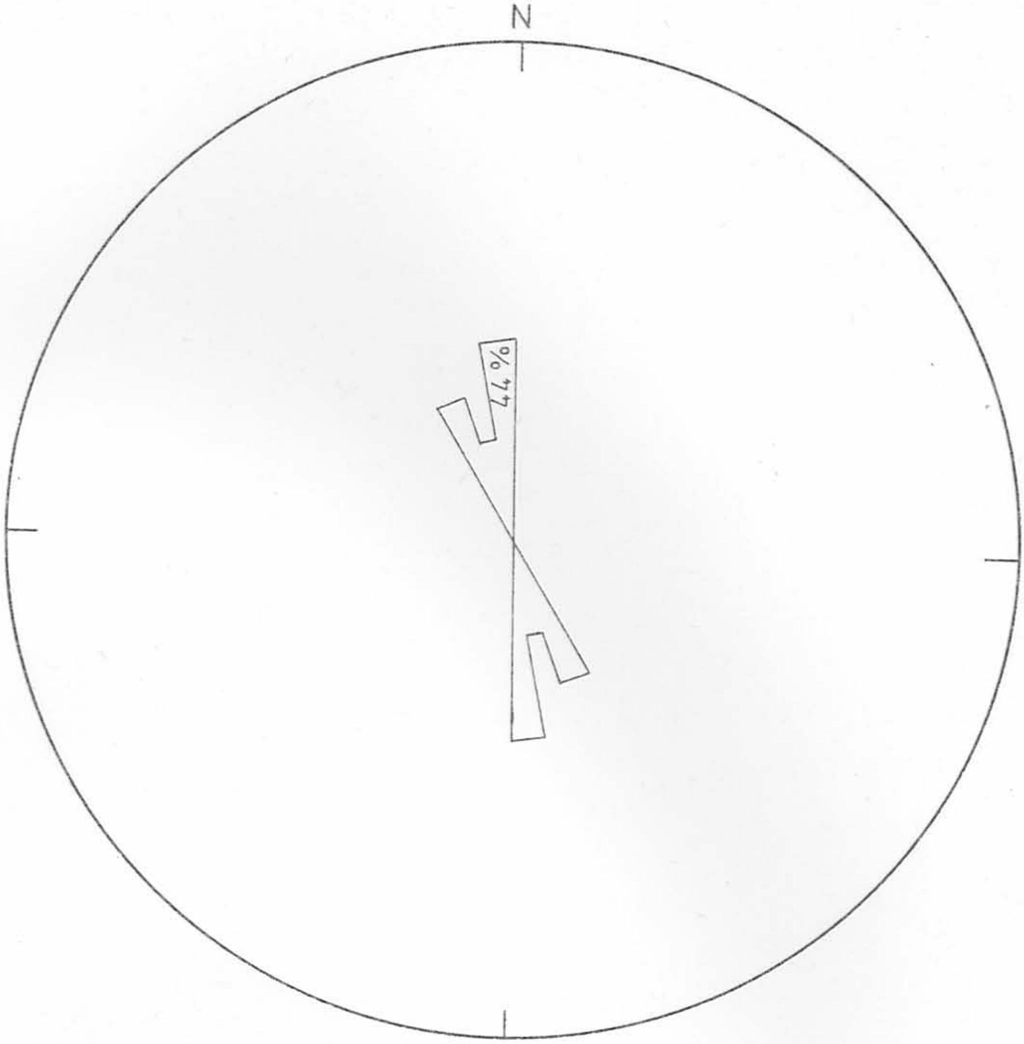
Wall pockets or solution indentations are common along cave walls,



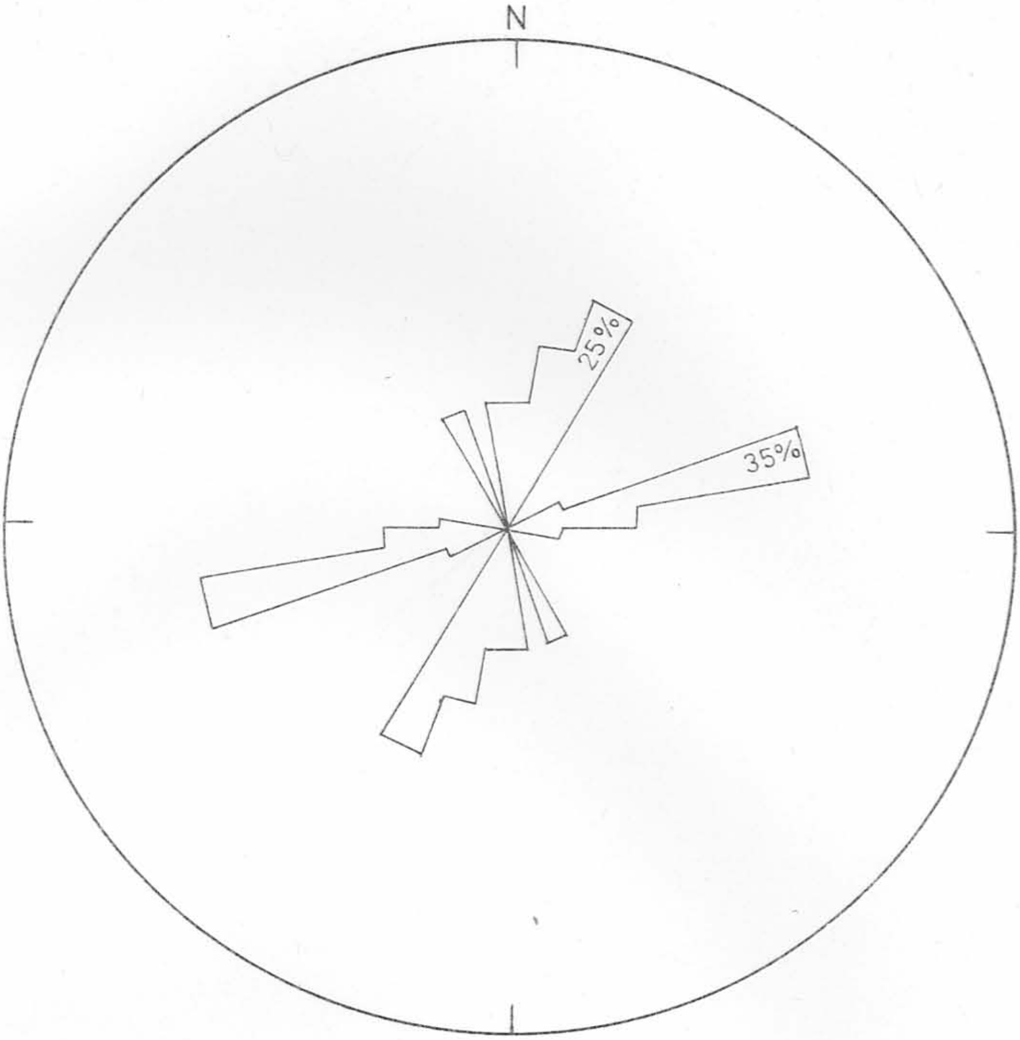
ORIENTATION DIAGRAM : JOINTING (39)



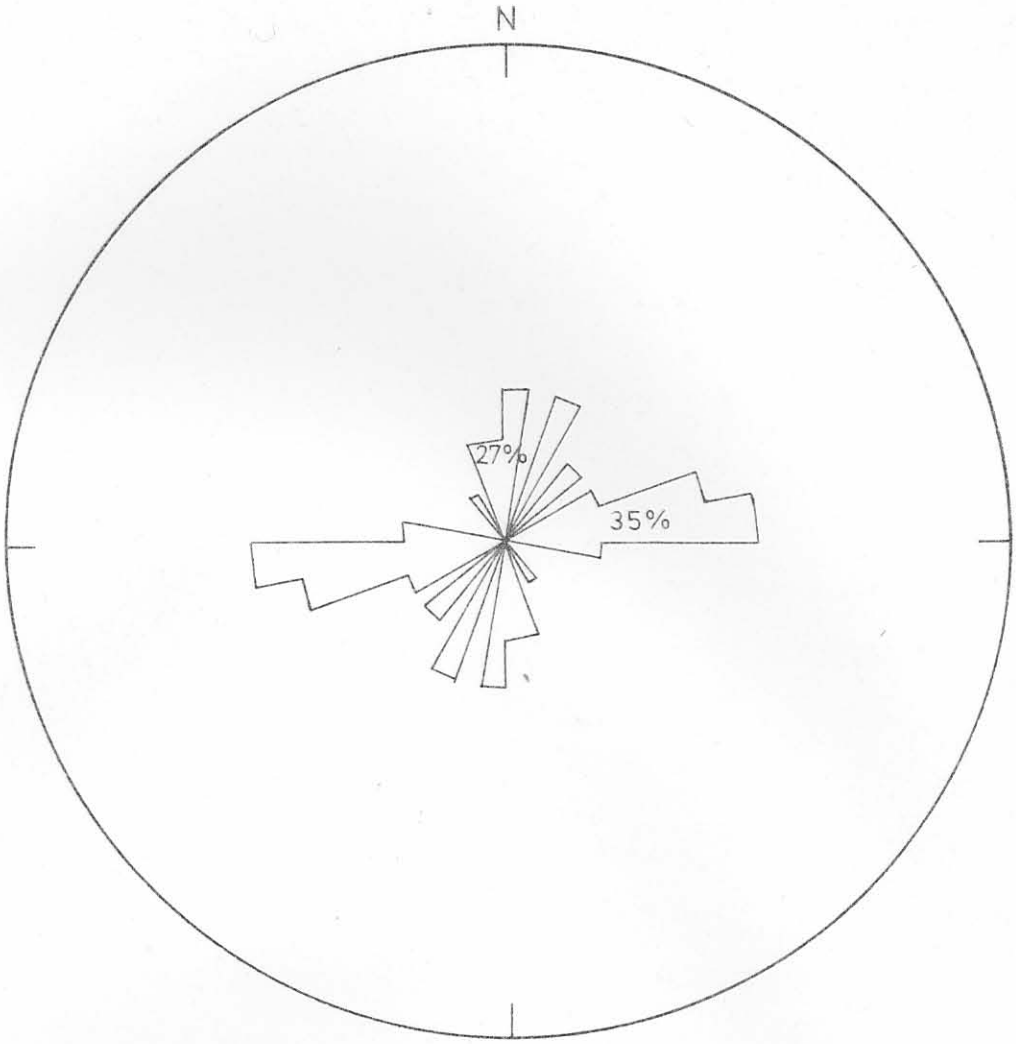
ORIENTATION DIAGRAM: DYKES (39)



ORIENTATION DIAGRAM: QUARTZ VEINS (9)



ORIENTATION DIAGRAM: GRAVEL RUNS (28)



ORIENTATION DIAGRAM: GRAVITY ANOMALIES (26) and it has been suggested that these structures are phreatic in nature and are formed below the water table (Bretz, 1942). Wall pockets are well developed in the dolomite cliffs of King's Pothole. They are roughly circular and range from 0,2 m to 1,5 m in diameter. One of the larger wall pockets displays a prominent arched column of remnant dolomite, 2,5 m in length and with an average inclination of 60°. Similar structures are to be found at Malan's Pothole and in a cave which was discovered between Bakerville and the main Lichtenburg-Zeerust road. The preservation of such features within these wall pockets would indicate that dissolution occurred during weak current activity in such water-filled cavities.

Moneymaker (1942) described solution cavities both below and above the water table in the Tennessee valley. Although the development might have started under the water table, a major portion of the enlargement was done above.

In his studies of the Transvaal caverns Brain (1958) recognised two definite types, viz., solutional and subsidence caves. In both cases irregularly shaped chambers are dissolved out by phreatic waters immediately below the water table. Structural weakness in the dolomite aided the development of caverns. Through lowering the water table by surface erosion and climatic change the caverns are elevated into the vadose zone. In this zone the chamber is enlarged by the dissolving action of water seeping through the joints and the ultimate collapse of the roof-developed sinkholes.

Retief (1960) describes the pre-Karoo surface as a peneplain formed by partially denuded Transvaal rocks presumably covered only by outliers of rocks of the Waterberg Group. Dwyka glaciation probably removed all the arenaceous rocks and laid bare the dolomite and solution of the dolomitic limestone was then in progress. Tillite was deposited on the dolomite covering the erosion surface of the pre-Karoo peneplain.

Harger (1922) visualised that whilst deposition of the Karoo beds occurred percolating waters were already finding their way downwards and developing caverns in the dolomite.

In post-Karoo times denudation set in and river systems started to develop and incised deeply into the Karoo bedrock, the prominent drainage direction being south-westerly. That little of the dolomite has been stripped since its exposure by the removal of the Karoo cover and that the existing peneplain is not very different from the pre-Karoo erosional surface can be deduced from the following observations; (1) Karoo rocks still exist at Pienaar's Pothole (Du Toit, 1951; Stettler, 1979) and, (2) other outliers of Karoo rocks also exist in the area especially around Lichtenburg. The dolomite is nearly horizontal so that the area has been very stable since post-dolomite deposition. There is very little change in elevation between Lichtenburg and Bakerville so that the actual contact between the dolomite and the overlying Karoo rocks was not far from the existing peneplain.

As the denudation of the Karoo sediments progressed dolomite was laid bare again and karstic surface features developed on the exhumed former peneplain. In addition to these erosional forms a honeycombed subsurface pattern existed in the dolomite. The water table was still relatively high. A further development of the underground solution cavities would tend to be concentrated in the areas underlying the valleys as it is these regions where the dolomite was first laid bare.

Denudation of the sediments progressed at such a rapid pace that the load of the rivers was out of proportion to their capacity and during severe floods debris was moved over considerable distances.

Many present-day braided rivers are found on piedmont fans along the flanks of highlands from which discharge is often seasonal, e.g. as from the Rocky Mountains into the hot desert of the mid-western United States, and along the periglacial mountains in Canada (Blissenbach, 1954; Williams and Rust, 1969). Although flanks of highlands were not all round, certainly the mountainous divide between the dolomite and the Pretoria series was much further south and closer to the Lichtenburg gravels, than presently. In these regions mechanical erosion is rapid, discharge sporadic, but volumetrically vast and there is little vegetation to hinder runoff. Rivers are generally overloaded with sediment. Repeated bar formation and channel branching generates a network of braided channels over the whole depositional area. Therefore the alluvium of the braided rivers is typically composed of sand and gravel deposits, similar to those found in the Bakerville district. Due to repeated channel switching and a fluctuating discharge there is generally an absence of laterally extensive cyclic sequences, such as those produced by meandering streams (Selly, 1969).

During severe flood conditions, overflow would cause finer material to be deposited outside the main river channels to form thin and finer gravels whose ratio of matrix to pebbles is much higher than that of the main runs (fig. 31).

The dendritic shape of the morphology of the gravel run, the width of the major gravel runs and the size of some of the boulders indicate that the rivers were large and that the initial capacity to move and remove material at flood conditions was great.

Potholes developed in or alongside the riverbed. Those which occurred near enough to the channel were filled with finer gravel in times of severe floods when the rivers were overloaded with sediment. The influx of gravel in these sinkholes was very gradual and the churning action of the currents in the potholes caused the concentration of diamonds in the basal layers of each cycle.

The relative lowering of the water table caused the rivers to lose their capacity to transport material further as the drainage changed from subaerial to underground as the result of the development of karst

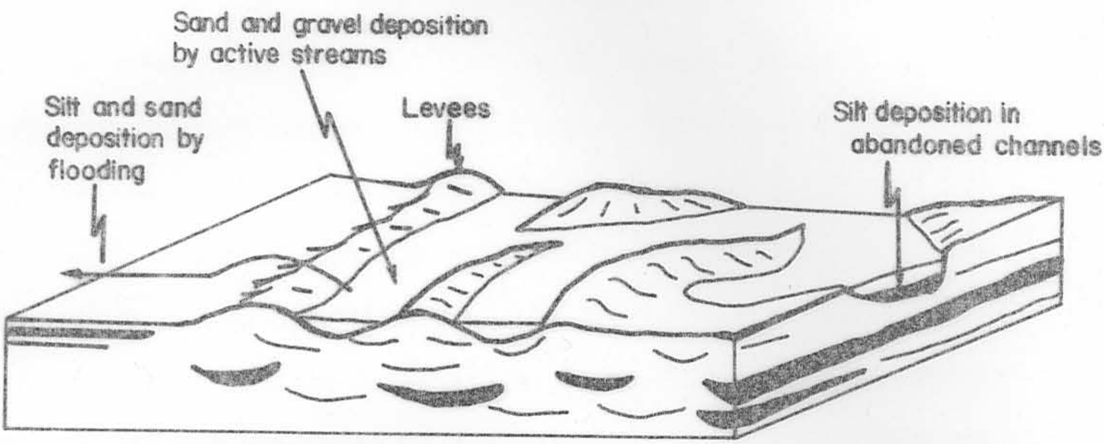


Figure 31 Origin of alluvial sub-facies deposited by braided rivers(after Selly 1969).

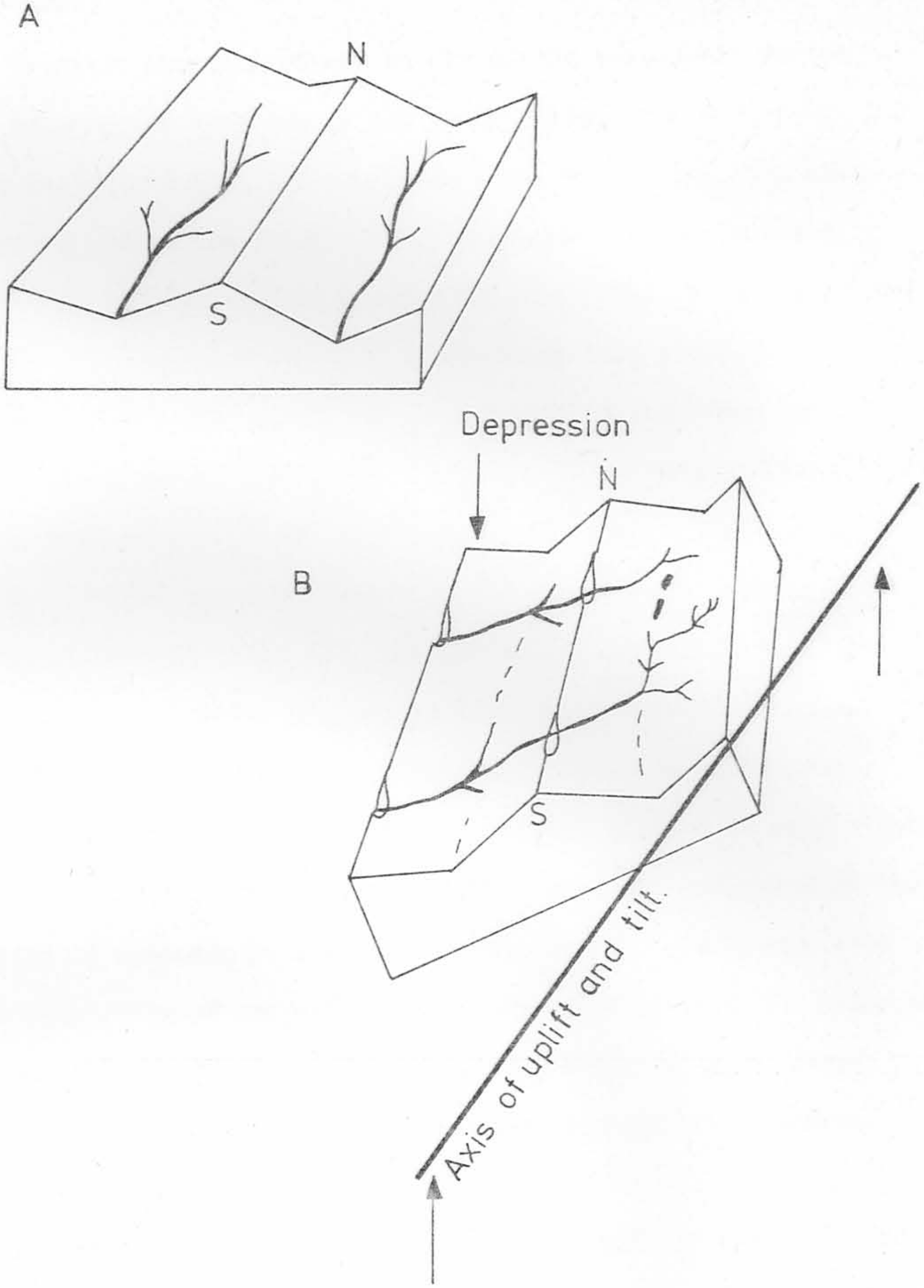
topography.

Two unrelated forces are thought to have instigated the relative lowering of the water table namely climatic fluctuation and late-Tertiary crustal uplift.

It is generally agreed that periods of both wetter and drier climatic conditions have occurred during this period in Southern Africa (Marker, 1972). During the wetter periods water would have been available for dissolution under high water table conditions. In the intervening dry periods the water table would have been lower and flash floods common (Bond, 1967). Late Tertiary crustal uplift along the Griqualand-Transvaal axis would cause a dramatic change in the drainage system (Mayer, 1973; Du Toit, 1933) and in the regional hydraulic head of both the surface and underground waters (fig. 32). Mayer (1973) proposed that the Welverdiend-Grasfontein run during its mature stage formed a tributary of the Harts River. Due to the uplift of the Griqualand-Transvaal axis, tributaries of the Molopo River cut off the headwater of the palaeo-Harts River so that the Welverdiend-Grasfontein-La Rys Stryd tributary was directed towards the north-west.

On the map accompanying Du Toit's paper (1933) the Griqualand-Transvaal axis of uplift is shown as passing through Lichtenburg. For geological as well as geomorphological reasons it is expedient to move this line further south and Mayer (1973) suggests that it coincides with the present divide of the Harts and Vaal rivers.

The dykes which cut the dolomite have a significant influence on the water table. They act as barriers and divide the dolomite into compartments. However due to the tilting of the area which was caused by the axial uplift, the axis of which is to the south of the study



THE UPLIFT ALONG THE GRIQUALAND-TRANSVAAL AXIS CAUSING A DRAMATIC CHANGE IN DRAINAGE DIRECTION (After MAYER 1973) area, a relative lowering of the water table will be experienced in each compartment.

Every climatic change from wet to dry during the uplift period would also enhance the lowering of the water table.

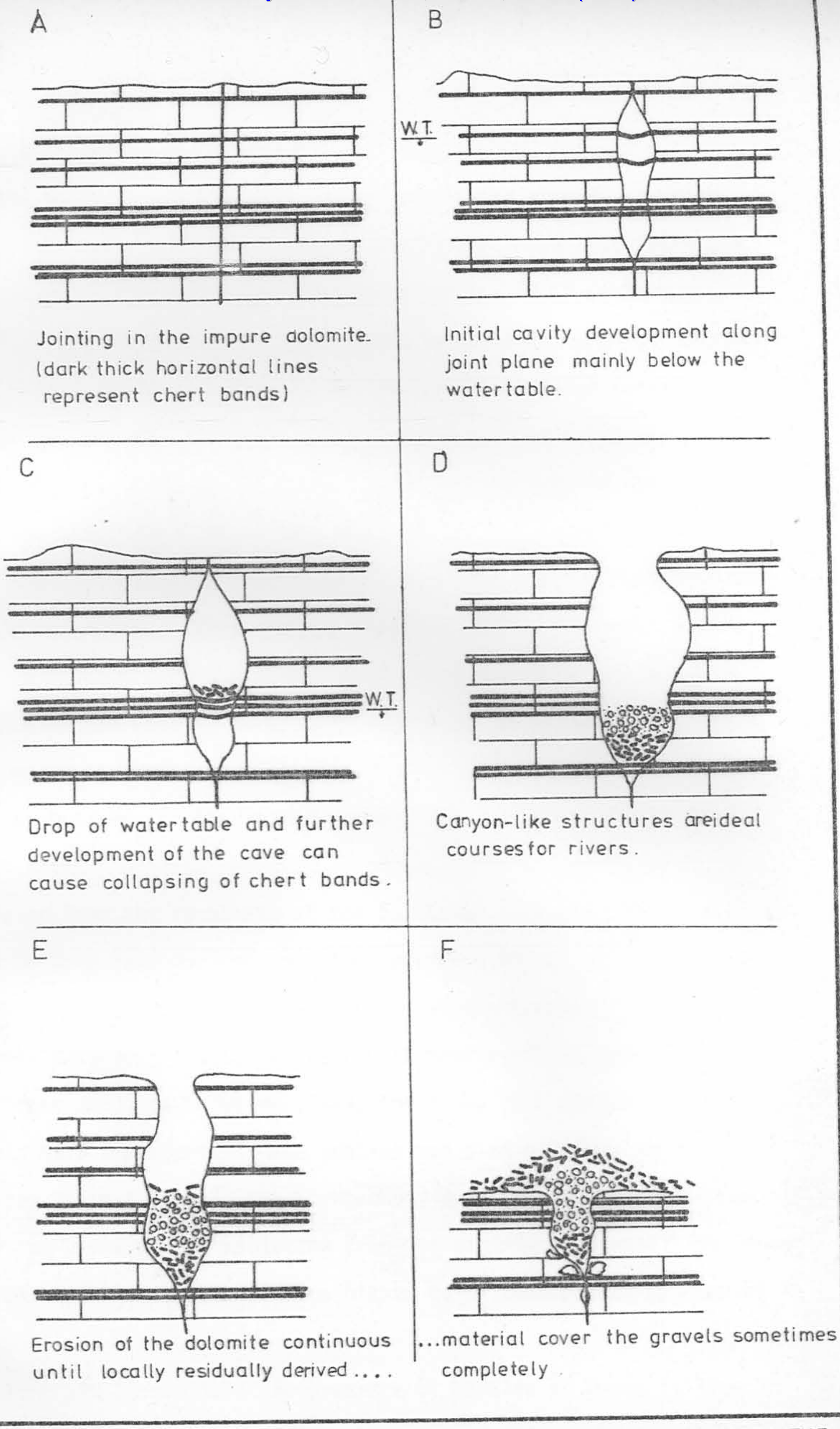
In the Bakerville area the sharp outlines of the runs, the absence of any slumping within the gravels or of collapse features where a potato gravel is resting against a dolomite wall (figs. 6 and 7, around peg 800/2900) all suggest that little subsidence took place in the river courses, except where potholes were formed in the river bed.

Some of the gravels found their way into the already existing sink-holes at the time of deposition (e.g. King's Pothole). Collapse of the dolomite walls of such a pothole burying the gravels under a thick layer of dolomite/chert (fig. 33), can be clearly observed around peg 1000/2850 (fig. 21, borehole 9), and at King's and Malan's potholes.

It has been suggested (Retief, 1960) that some reworking took place at the edges of the runs. This is in fact evident in many places, and indicates that reworking probably had an important influence on the concentrating of diamonds in the runs. The last cycle of deposition before the completion of the axial uplift was manifested by the sediments of the "Rooisloot" which cuts obliquely across older drainage lines. The change in gravel morphology suggests that this cycle represents change in climate.

A final comment is justified on the preservation of the gravels. Both to the north and the south of Bakerville their traces vanish. It is most likely that the actual physical characteristics of the karst area was responsible for the preservation. Would the bedrock have been granitic for instance, then the remaining gravel would probably be less extensive in aerial distribution or perhaps non-existent.

The above scenario and sequence of events is thought to best explain the features of the Bakerville gravels as well as their stratigraphic



DEVELOPMENT OF A CAVE IN ANIMPURE DOLOMITE AND THE SUBSEQUENT DEPOSITION OF THE GRAVELS.

setting.

7.2 Origin of gravel and diamonds

On the basis of lithological variations in the gravels, coupled with palaeocurrent directions Stratten (1979) concluded that there are three distinct source areas for the gravels of the south-western Transvaal. The first and most prominent, is situated north of Swartruggens. This is the source area for the Lichtenburg/Ventersdorp gravels (Stratten, 1979). Other source areas such as south-eastern Botswana, which were supposedly responsible for the gravels near Mafikeng and Schweizer-Reneke were less influential (Stratten, 1979). Prior to the Tertiary upwarping in this area, the watershed was located further to the north. Thus eroding streams flowed southwards, with a tendency to radiate from the source area (Stratten, 1979). This is in agreement with the work of Mayer (1974) from which Stratten argued that tectonic movement during the Tertiary disrupted the south-eastern drainage tributaries in the Swartruggens-Lichtenburg area of the Vaal catchment area.

Judging from the roundness of the quartzite pebbles, which are believed to have been derived from the Waterberg Group, Stratten (1979) estimated that they could only have travelled approximately 60 km. The nearest Waterberg quartzite outcrop is nearly 110 km away (in the central Transvaal), so Stratten (1979) concluded that the only medium that could have transported these pebbles and diamonds from pre-Karoo kimberlites in that area to the Lichtenburg area was the Transvaal ice sheet of the Dwyka period radiating from the central Transvaal. Subsequent erosion of the tillite released the clasts to be transported by fluviatile forces.

Du Toit (1952) mentions the presence of pebbles of Dwyka tillite in the Bakerville gravels and reports the sporadic occurrence of silicified wood on Grasfontein 356 JP both of which must have been derived from the Karoo sequence.

If the source area of the Bakerville gravels was identified correctly as being just north of Swartruggens (Stratten, 1979) one must conclude that the source of the diamonds, be it primary or secondary, is somewhere between Swartruggens and Bakerville, a distance of approximately 100 km. However, samples taken from the gravel runs at Bakerville failed to produce any kimberlitic minerals which could be identified beyond doubt. The samples also include concentrates from King's and Malan's potholes (see section 6).

It is unlikely that the diamonds were derived from the Swartruggens kimberlite dykes as the physical characteristics of the diamonds of the two areas differ distinctly, even if the dykes were part of a system of kimberlitic diatremes which are now eroded away (Dawson,1972).

It has been suggested (Stettler, 1979) that a yet unidentified diamondiferous kimberlitic source exists in the immediate vicinity to the east or north of Lichtenburg. The lack of abrasion of the diamonds and the presence of cleavage "chips" are supposed to be in support of this idea. However, diamonds with such physical characteristics are also found in the beach deposits at Oranjemund (J.B. Hawthorne personal communication).

Detailed loam sampling for heavy minerals in the immediate area of the gravels and in the Lichtenburg district, by the prospecting group of the De Beers Consolidated Mines, failed to even pick up any kimberlitic grains (Mr J.B. Hawthorne, personal communication).

Examples of diamondiferous sediments close to a primary source such as Swartruggens (Transvaal), Premier (Transvaal), Lethlakane (Botswana), Orapa (Botswana), all yield large quantities of kimberlitic minerals such as garnets, ilmenites and chrome-diopsides, which are lacking in the Bakerville gravels.

The author finds it highly unlikely that a primary diamond source is either in or close to the Lichtenburg diamond fields.

It thus seems reasonable to conclude from the abundance of diamonds and the lack of other kimberlitic minerals in the gravels that the history of the diamonds after liberation from their primary source, is more complicated than the formation of the gravels themselves.

As the Dwyka tillite is being considered a likely source for the foreign clasts in the Bakerville gravels, (Stratten, 1979) the tillite must surely be considered a likely source for the diamonds in these gravels. This was first suggested by Harger (1914).

The Transvaal highland area was one of the major ice producing centres in Southern Africa during the Dwyka glaciation (Stratten, 1977). The south-western Transvaal was invaded by the massive Transvaal ice sheet which radiated outwards from the Transvaal highlands. In the south-western Transvaal the main direction of flow was towards the south-west at the close of the glacial period (Stratten, 1967). The primary source of the diamonds must therefore have been to the north-east of the Lichtenburg-Swartruggens area. It is postulated that the pre-Karoo kimberlites were eroded by the advancing ice sheets and that the kimberlite debris became incorporated in the tillite.

Studies made on the chemical stability of garnet have provided a variety of results. The general consensus, however, is that garnet is only moderately stable under soil-forming processes but once buried shows a high resistance to further weathering by intra-stratal solution (Pettijohn, 1941; Gravenor, 1954).

It was found that a large percentage of chattermarked garnets, taken from the late-Palaeozoic glaciogenic deposits in the Kimberley area, was the result of a much longer distance of transport probably because of continuous recycling (Gravenor, 1979). Gravenor (1979) concluded that the concentration of heavy minerals and the loss of unstable minerals is in large measure due to mechanical abrasion, which took place during interglacial periods when the heavy minerals were subjected to reworking in lacustrine and fluvial environments.

As the ice vacated the depressed basin, the sediment in the basin was reworked (Gravenor, 1979). Under these conditions the less mechanically stable minerals were broken down, leaving concentrates of diamonds and to a lesser extent, garnets. As the ice re-advanced heavy mineral concentrates were picked up by the ice, reworked and redeposited. After many cycles of this nature, the heavy minerals in the glacial deposits became enriched, (Gravenor, 1979).

Once liberated from the tillite, these minerals became exposed to different chemical and mechanical weathering processes. After transport to and deposition in the Lichtenburg area diamonds, being the most stable of kimberlitic minerals, will eventually occur in largest concentration.

Although the occurrence of small garnets in very small quantities and only found in some of the major potholes (e.g. Pienaar's Pothole) has been reported (Du Toit, 1951; Stettler, 1979) it appears that the diamonds from the Bakerville gravels are the only remains of the primary source.

It would be a rewarding experiment to analyse these garnets for chattermarks and other surface features.