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VAALHARTS IRRIGATION SETTLEMENT

Geologist's Preliminary Reclamation Report before visiting the area

by

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INTRODUCTION - SOURCES OF INFORMATION

This report is based on the study of the air photographs covering the irrigation settlement supplemented by studies of the following items:

1. All available topographical maps including the Vaalharts irrigation maps which show contours at vertical intervals of 5 feet.

2. All available geological maps, those of the largest scale being the 1907-08 Geological Commission maps on the scale of approximately 4 miles to the inch.

3. A map of the irrigation settlement on the scale of 1 inch to 3000 feet giving plot reference numbers and showing the system of irrigation canals and drainage ditches.

4. The original soil type and irrigability maps at the Soils Research Institute covering the settlement.

5. Soil Groups and Sub-groups of South Africa by C.R. van der Merwe (1940).

6. Various interim reclamation reports by A. Streutker and members of the Water Affairs Department which were circulated prior to the field conference held at Jankempdorp on 8th-9th August 1967.

The writer has also had the benefit of personal discussions with Dr. C.R. van der Merwe, Mr. J. van Woerkom and Mr. Louw of the Soils Research Institute, Pretoria.

1. WATER AND SOIL IN THE HARTS VALLEY

The existence of the Vaalharts irrigation settlement is dependent on the topographic circumstance that water can be diverted from the Vaal river into a 50-mile long reach of the Harts-Dry Harts river valley which carries irrigable soil.

(a) Water

The topographic circumstance exists for the following reasons (fig. 1). The Harts river, rising near Lichtenburg, flows southwestwards across the western Transvaal gradually converging with the Vaal and debouching into that river at Delportshoop.

At Schweizer Reneke the Harts river is 40 miles from the Vaal, at Taung 35 miles, while at Warrenton on the Vaal the distance between the two rivers is only 15 miles.

The irrigated belt of land is not entirely in the Harts river valley, for, above Taung, it extends northwards in the valley of the Dry Harts river, not that of the Harts. For this reason the irrigated valley is referred to in this report as the Harts-Dry Harts valley or simply the HDH valley.

The Vaal and the Harts rivers above Warrenton and Schweizer Reneke, respectively, both traverse the plateau of the south-western Transvaal and have very similar long-valley profiles but between Schweizer Reneke and Taung the Harts river descends into the comparatively deep north-south trending HDH valley, while the Vaal at Warrenton situated 40 miles south of Taung has not yet begun its descent into that valley; hence Warrenton stands some 175 feet above Taung and 500 feet above the Harts river at the latitude of Warrenton.

It was thus possible to lay out irrigation canals to water a 50-mile long strip of land, situated between them and the HDH river, which is 3 miles wide at Pudimoe, 8 miles at Taung, 9 miles at Hartswater, 13 miles at Jankempdorp and 6 miles wide at the southern end of the western canal. The corresponding elevation differences between the canals and the rivers are 75 feet at Pudimoe, 180 feet at Taung, 425 feet at Jankempdorp and about 300 feet at the end of the west canal.

(b) Soil

Most irrigated soils other than alluvial are residual soils characteristic of some particular rock type or, more frequently, characteristic of some particular drainage conditions in the topographical catena.* The Vaalharts settlement soil is exceptional as it is an aeolian transported soil named by C.R. van der Merwe (1940) after the material in which it has developed, viz. Kalahari Sand.

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*Catena means chain. It was applied first by Miln to the succession of soil types characteristic of different positions in the topographical profile in the Shinyanga District of Tanganyika. I extend its use to the succession of topographical elements themselves. See fig. 8 of this report.

In the central and greater part of the Kalahari region the soil profile contains no calcrete horizon, but in the peripheral belt of the Kalahari, in which the HDH vally lies, the presence of a calcrete horizon is a normal feature of the soil. Van der Merwe regards the calcrete as the B horizon of the sandy soil and distinguishes this peripheral soil with the calcrete horizon as a separate sub-group "Kalahari Sand on Lime" different from the "Kalahari Sand" of the central part of the Kalahari. Van der Merwe believes that the sand of the Kalahari Sand on Lime soil was blown by the wind from its source in the central Kalahari onto non-arenaceous bedrock formations in the peripheral region and that the calcrete B horizon developed in it there, not by the usual downward leaching process from the surface but by deposition from soil water that moved upwards under capillarity from slightly calcareous rock and subsoil below. Where calcrete is exposed at the surface, he infers removal of the overlying sand by wind or other means.

As in this report we are not much concerned with the genetic relationship of the sand and the calcrete, the sand will be referred to simply as the Kalahari sand and the limestone horizon simply as the calcrete. The sandy nature of this soil, while rendering it irrigable, is, the author believes, in association with the impermeability of the underlying rock, one of the main reasons for its having become water-logged by the irrigation water.

2. GEOLOGY AND GROUND-WATER MOVEMENT

(a) Geological structure of the valley

North of Kimberley the northeastward trending Dwyka outcrop becomes split into two narrow projections by an anticlinal Ventersdorp inlier. The Dwyka outcrop projection lying east of the Ventersdorp inlier runs up the Vaal valley where it is terminated by the overlap of the Ecca onto the Ventersdorp; while the Dwyka outcrop projection lying west of the Ventersdorp inlier extends up the HDH valley to be terminated by erosion in the neighbourhood of Vryburg. A map traced from the Geological Commission maps of 1907-08 and covering the Karroo outcrop projection in the HDH valley is presented as figure 2 of this report.

The HDH valley runs north-south because in this part of the country most formational boundaries and structural lines such as faults and master joints run north-south, or nearly so, while the regional dip is low and mainly in a westerly direction as indicated in the diagrammatic section fig. 3.

The HDH valley was excavated in pre-Karroo rocks in pre-Karroo times and because it lies just north of the main Karroo outcrop, the basal formations of the Karroo, viz. those of the Dwyka Series, have been preserved, in part, in the valley. Because of the lesser resistance to erosion of the Dwyka formations than those of the pre-Karroo systems, this HDH valley has been partially re-excavated during the present cycle of erosion leaving a belt of Dwyka rocks lying on its floor. The Dwyka is now confined to the valley pediments.* Its thickness below the beds of the rivers is unknown but laterally it thins out altogether at or near the upper edges of the pediments.

Examination of the air photos shows that the western edge of the Karroo outcrop in the HDH valley is, for several miles, a faulted contact with the underlying Dolomite. It is possible, therefore, that the pre-Karroo HDH valley may have been in part a fault trough valley and also that the thickness of the Karroo preserved in the re-excavated HDH valley may have been slightly increased by post-Karroo down-faulting on the western side. No such fault has been found on the eastern irrigated flank of the valley.

Between the Ventersdorp forming the upper eastern valley side and the Dolomite forming the upper western valley side there intervenes stratigraphically the formations of the Black Reef Series. A little to the north of Pudimoe and to the south of Delportshoop, Black Reef formations are exposed in their proper stratigraphical position so it must be assumed that between those points there extends a long, narrow sub-outcrop of these formations concealed beneath the Dwyka. The presence of north-south strike faults both in the Ventersdorp to the east and the Dolomite to the west raises the possibility that the Black Reef may have been prevented from sub-outcropping due to displacement by a strike fault concealed by the Dwyka but, in the absence of evidence to this effect, the existence of concealed Black Reef formations has been indicated in the generalised cross section. Regarding

*Pediment is a geomorphological term used by L.C. King (1957) and is the lowest topographical element or link in a fully developed hill slope. See fig. 8 of this report.

the movement of groundwater, it is probably immaterial whether Black Reef formations have a sub-outcrop or not.

The irrigation belt lies entirely on that part of the Dwyka that forms the left bank or eastern pediment of the HDH valley except that where formations of this series thin out to the east, numerous hills and rises of Ventersdorp rocks project through the Dwyka.

(b) Ventersdorp System

According to the Geological Commission maps (1907-08) fig. 2, the greater part of the Ventersdorp outcrop in this area consists of volcanic and minor intrusive rocks; the former include pyroclasts and most are basic. But roughly between Taung and Jankempdorp there is an outcrop of sedimentary rocks about 20 miles long and 4 miles wide which consists mainly of arenaceous and rudaceous types. Though the Dwyka locally thins out onto these sedimentary formations, they apparently do not extend far under the Karroo for they are terminated to the west by a strike fault which brings the igneous rocks back to outcrop both at the surface and under the Karroo.

From the point of view of ground-water movement it is probably of no significance what different types of Ventersdorp rocks are present for they are almost certainly all impermeable except where weathered at or near the surface and in depth where cut by faults and master joints.

Examination of the air photos, parts of job 430 (1959) and job 497 (1963), shows that the Ventersdorp rocks, both igneous and sedimentary, are cut by several faults and systems of master joints. The fault forming one of the boundaries between igneous and sedimentary rocks has already been mentioned. In the rough scarp country forming the upper slopes of the HDH valley the traces of these faults and master joints are revealed on the air photos as linear stream beds, lines of bushes and trees, and gaps in scarps. In the undissected plateau country east of the valley side, the presence of pans is regarded as indicating as many points of intersection of these structures. North-south and NNW-SSE striking structures seem to be the strongest and most continuous but numerous cross and oblique fractures are present and their spacing apart varies from a few hundred yards to several miles.

Any ground-water that exists in the rocks of the Ventersdorp System is almost certainly restricted to openings in these faults and master joints and its movement within these structures will be limited to systems of connected openings within the fracture planes. There will be movement of ground-water westwards from the plateau to the valley via such labyrinthine networks of cracks and also down-valley in the Ventersdorp underneath the Dwyka, also via openings in faults and master joints, but whether this deep ground-water has any influence on the irrigation system is very doubtful for to reach the soil it would have to rise up through the covering of Dwyka which is probably even more impermeable than the Ventersdorp rocks themselves.

Ground-water in the Ventersdorp is generally not highly mineralised and is quite suitable for agricultural purposes so that even if it does contribute to the shallow ground-water body involved in the irrigation, it would not be detrimental from a salinization point of view.

(c) Black Reef and Dolomite Series

According to the 1907-08 geological maps, the Black Reef Series consists of almost exactly the same kinds of igneous and sedimentary rocks as the Ventersdorp though diabase is not mentioned and flagstones are present instead of conglomerates. Where unfractured, these rocks will probably be as impermeable as the Ventersdorp but they are likely to have been cut by the same or similar faults and master joints and so will transmit ground-water in the same way. This water is not likely to contain more dissolved mineral matter than that in the Ventersdorp.

West of the Dwyka outcrop there is only the Dolomite Series which consists mainly of dolomite but carries some interbedded cherts and shales. Dolomite is impermeable except where solution fissures and caverns have been opened in it. To what extent this has occurred in the dolomite west of the HDH valley has not been ascertained but in any case, the dolomite dips away from the valley so that any ground-water it may contain must be shed at springs at or near the western edge of the Dwyka formations that cover the dolomite on the valley floor. The Thabaseek springs at Buxton Lime Works are of this origin and there are probably others lying to the north and south of them. Such surface water of spring origin will contribute to the shallow ground-water that occurs in any part of the Dwyka rendered permeable by weathering but is unlikely to effect the irrigation system which is confined to the east side of the HDH valley.

(d) Dwyka Series

According to the 1907-08 geological maps the Dwyka consists of shales and boulder beds (since recognised as tillite). Numerous outcrops of dolerite are marked which are the eroded relics of one or more dolerite sills or sheets intruded among the shales. None of these igneous rock outcrops occur within the main part of the irrigation belt but scattered patches of irrigable ground lie on them in the lower parts of the valley pediment.

Several equatorially and meridionally orientated dolerite dykes have been mapped in the dolomite area west of the HDH valley but none in the Ventersdorp or Dwyka outcrops to the east of or in the valley. A dyke reported by Paver (1939) as diabase is said to be followed by the Pokwani spruit near Hartswater and a "reef" reported by A. Streutker at Tadcaster Primary School may be another.

The Dwyka shales and tillites are impermeable rocks except where decomposed by weathering or fractured by faults and master joints. The depth of weathering is generally very small,# especially in this case where the Dwyka beds are for the most part buried under calcrete and Kalahari sand. Examination of the air photos reveals no lineaments* on the Dwyka outcrop east of the HDH rivers such as might be interpreted as the trace of a fault or master joint. Therefore, except for the very limited permeability deduced from considerations relating to calcrete and to the composition of the ground-water discussed below, it must be assumed that below a very thin# weathered zone the Dwyka rocks are even less permeable than the older formations. The dolerite sheets probably weather more deeply than the shales and tillites but as they do not occur in the main part of the irrigated area, their influence on the irrigation problem is not important.

#: See addenda and corrigenda

Shales, tillites and dolerites are converted to clay on complete weathering so that beds of clay reported to underlie the Kalahari sand or calcrete may be derived by the weathering of Dwyka rocks either before or after burial by Kalahari sand.

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*A lineament is a linear feature seen on an air photograph which is regarded as having a geological origin.

Ground-water in the Dwyka is among the most highly mineralised ground-waters to be found in South Africa. The upper Dwyka shales in particular are usually carbonaceous and rich in the iron sulphides, pyrite and marcasite, and many commercial salt pans occur on this formation. Whether the particular shale beds that underlie the irrigated area are especially rich in sulphates and chlorides is not known, but the irrigation water that stands upon them certainly becomes locally highly mineralised with these salts. How much deep ground-water seeps out of the shales into the shallow soil water introduced by irrigation is not known but, where soil drainage is deficient, evaporation and transpiration are so effective that water, which has become mineralised by standing in the ~~thin~~ zone of weathering in the shales is drawn up into the soil and evaporated there, with the consequent deposition of its content of dissolved salts.

There is apparently no bore-hole in this area the log or hydraulic result of which have been recorded by a geologist. The very few drilling results available have been supplied by boring contractors either in writing or verbally. The data supplied regarding the nature, depth and succession of geological formations penetrated are generally so incompatible with what a geologist is naturally lead to expect from his surface observations and general experience, that all such data are regarded with the utmost suspicion.

There are records of one bore-hole on the farm Dawlish and four on the farm Hartebeestepoort drilled in 1939 on sites chosen by G.L. Paver. The location of these farms and bore-holes has not yet been ascertained. The drillers' logs record limestone, shale, quartzite and diabase. The limestone is presumed to be the calcrete. The other formations seem to be sedimentary Ventersdorp but are more likely to be Dwyka.

According to the drillers' logs, three of the four bore-holes on Hartebeestepoort penetrated 50 feet of calcrete, the fourth none. One bore-hole was dry and the other four had yields between 360 and 1000 g.p.h. In one hole water was struck at 120 feet and in the other three at two or more depths ranging from 87 to 205 feet. The rest levels in the three successful holes were 80, 90 and 90 feet.

The various depths at which water was struck and the fact that it rose to a higher rest level seems to confirm that groundwater in any useful quantity only occurs as confined water in fractures in otherwise impermeable rock. At the time these holes were drilled the irrigation scheme had been in operation for six years by which time water-logging and salinisation had already become apparent in some places. A well 140 feet deep, reported to have been dry before the irrigation started is now full of water. Evidently before irrigation, there was either no water table or it stood at a greater depth than 140 feet; then, as a result of irrigation, the surface water from the irrigation furrows seeped down to fill up all intersticies that were dry or to join the natural ground-water and raise its level until ground-water and irrigation water became a single body. A little run-off water from the surface drainage of the Ventersdorp country east of the canals may infiltrate to join the irrigation water but it is by no means certain that any deep ground-water at all emerges to join the irrigation water in the soil. No springs, flowing wells or bore-holes have been recorded in the irrigation area such as would indicate the presence of artesian water.

(e) Calcrete

Before it is possible to complete the picture of probable water movement in the soil, it is necessary to understand more about the calcrete and Kalahari sands than was stated in the introductory paragraphs.

A study of the soil type maps prepared in advance of the irrigation scheme indicates that a formation of calcrete intervenes between the bedrock and the Kalahari sand over the greater part of the area between the irrigation canals and the HDH rivers. Near the canals it is interrupted by bedrock generally of Ventersdorp lava, rising through the thin edge of the Dwyka shales and tillite. Near the Harts river both Kalahari sand and calcrete have generally been removed by erosion and the edge of the remaining part of the calcrete formation forms a subdued scarp overlooking the Harts river. The continuous strip of irrigable land is of course restricted to the belt of country from which the calcrete formation and its overlying Kalahari sand have not yet been removed.

The calcrete formation must be thought of as having grown in the Kalahari sand as a sheet of rock, first by the coalescence of limestone pisolitic concretions and then by thickening of the sheet by mammillary or other replacement growths above and below.

Upwards the limestone replaced, displaced and enveloped grains of incoherent sand but downwards it reached the weathered zone of the Dwyka rocks underlying the sand and must in many places have started to replace both weathered and almost fresh rock.

This calcrete formation accumulated hundreds of thousands of years ago and is now undergoing erosion; in some places at the surface and in others, where it still forms the sub-soil, underground by root action. The calcrete is now, therefore, mainly in a cracked and broken condition so that, though the rock in the hand specimen may be impermeable, the formation as a whole is like a gigantic sponge that intervenes between impermeable bedrock below and highly permeable Kalahari sand above. This calcrete sponge, though permeable enough to allow capillary movement of ground-water upwards and infiltration of irrigation water downwards, will present a very effective barrier to lateral movement of water in the sand above it and in any patches of sand or permeable weathered rock that may have remained below it.

The movement of water with which we are mainly concerned is the movement of water in the sand above the calcrete so that the form of the surface of the calcrete under the sand is of paramount importance.

As plate 11, p. 63, Van der Merwe (loc. cit.) provides a photograph of an exposure of the "Kalahari Sand on Lime" south of Modder River Station. (See fig. 4 of this report.) Here the calcrete surface is pitted with so-called potholes up to 36 inches deep filled with sand. This type of calcrete surface would certainly impede lateral movement of water in the sand but whether it is typical of the whole surface of the calcrete sheet is not known. The upper edges of some of the calcrete ridges between the potholes have evidently been bevelled off by erosion along with the removal of the upper part of the sand, so that the pre-erosion surface of the calcrete may have been a great deal more rugged than is indicated by the part of it that remains. Van der Merwe attributes the potholes to the mode of accumulation of the calcrete but it is possible that they represent the remains of grikes* which are typical of the surface of a limestone formation weathered under soil. Whatever may be

*Grikes are deep open fissures developed on master joints characteristic of the weathered surface of limestone formations.

the origin of the potholes, the point at issue is whether their occurrence extends regionally under the sand into the irrigation area.

Certain areas have been seen on the air photos, situated on the lower parts of the HDH pediments, which exhibit a pattern of low white ridges rising a few feet above the intervening ground. A large area of this kind lies on the right or west bank pediment at the latitude of Hartswater (see fig. 5) and a smaller area, which is situated on the left or east bank pediment, occurs near a flat-topped spur projecting westwards towards the Harts river about two miles north of the lower end of Duncan Drain, west canal (see fig. 6).

Until these areas have been examined in the field, it is assumed that the white ridges are the outcrops of calcrete veins and that the lower, darker ground between them is underlaid by Dwyka shale or tillite or by a sheet of soil-covered calcrete lying upon such rocks. These areas are situated where the Kalahari sand with its calcrete horizon is in process of removal by erosion so that what is seen on the air photos may be the roots of the calcrete formation that have been laid bare. If this is the case, the veins would be formed of calcrete deposited in vertical cracks in the bedrock underneath the main part of the calcrete sheet which has been removed by erosion.

The significance of this structure is that the ramifying veins tend to subdivide the ground surface into pens of all sizes up to examples with diameters of about quarter of a mile. Though most of the pens are incomplete, their walls would probably constitute quite effective barriers to the lateral movement of water in an overlying bed of sand, if such existed; so that, <u>if this pen structure extends underneath the sand of the irrigation belt, it may be at least in part responsible for the water-logging that occurs there</u>. But, on the other hand, if the pen structure has developed as a surface form, only as the result of erosion after the removal of the sand, then there may be no pens where the sand has not been removed. This matter needs careful attention in the field.

(f) Kalahari Sand

The soil type maps of the irrigation belt and the air photos suggest that this sand is thickest along the upper or eastern flank of the strip of land lying between the irrigation canals and the rivers and that it thins out both eastward and westward. Eastwards near the canals, hills and rises of bedrock protrude through it and westwards, towards the lower slopes of the pediment, it has been partially or wholly eroded away to expose either the underlying calcrete formation or low rises of bedrock on which the calcrete may never have been deposited.

Discussion with Dr. C.R. van der Merwe reveals the facts that the Kalahari sand is both highly permeable and very friable. It is so permeable that much of the irrigation water sinks so rapidly through it that it passes beyond the crop root zone before the crops have had a chance to fully benefit from it. The consequence of this is that far more irrigation water has to be used than the crops need. This would not be a serious matter in the case of a well-drained soil but here, owing to the lesser permeability of the underlying calcrete, but due mainly to the almost impermeable character of the bedrock, this excess irrigation water cannot sink downwards. Therefore, where it cannot escape by lateral movement it becomes ponded and can only be dissipated by return to the surface where evaporation from the soil surface and evapotranspiration take place.

The question arises here, if the Kalahari sand is so permeable that the water infiltrates rapidly, how can capillarity be so effective as to bring it back again to the surface?

The writer has been led to understand that the friability of the Kalahari sand is such as to result in the instability of the walls of deep drainage ditches with their consequent collapse and in the choking of pipe drains by infiltrated sand. Watertight drain linings are also disrupted when the water-table rises to their level because the coherence of the sand is not sufficient to counteract the buoyancy of the linings in the water.

Where the Kalahari sand is so thick that the water-table in it stands well above any barriers formed by the surface of the underlying calcrete, lateral drainage in the upper part of the sand will not be interrupted. It is where the Kalahari sand is so thin that barriers closely approach the surface that most of the trouble must be experienced. It would, therefore, be useful to have an isobathic map of the thickness of the sand. Such a map could probably be compiled from the existing series of soil-type maps that cover the irrigation area. To prepare an isobathic map of the whole irrigation area would be most laborious but starts could be made at the most troublesome localities.

A useful consequence of the friability of the Kalahari sand may be the possibility of investigating its depth and form of the calcrete surface by the use of a post-hole auger. Another matter that requires investigation in the field is whether the presence of lateral drainage barriers can be located by the appearance of calcrete in the deep drainage ditches or in the banks of spoil derived from them.

3. TOPOGRAPHIC FORM AND SOIL IRRIGABILITY

(a) Topographic form

The Harts valley and its vicinity reveal erosion surfaces of four different ages as indicated in fig. 7. These are as follows:-

1. The pre-Karroo Harts-Dry Harts valley surface (a-a) eroded in tilted Ventersdorp, Black Reef and Dolomite formations and now represented only by the sub-Dwyka unconformity.

2. The post-Karroo peneplane surface (b-b) which bevels Karroo and older formations indiscriminantly and is now represented by the Dolomite and Ventersdorp plateaus on each side of the HDH valley.

3. The re-excavated Harts-Dry Harts valley surface (c-c), probably of late Tertiary age, eroded mainly in the Karroo forming the older valley filling but partly in the Ventersdorp and Dolomite of the valley sides. This surface is now represented by the HDH pediments in Dwyka and the higher hill slope elements in Ventersdorp and Dolomite.

4. The surface of incision (d-d) of the Harts river, probably since early Pleistocene times, into the lower parts of its former pediments, which consist of Kalahari sand, calcrete, Dwyka formations and dolerite sills. This surface is now represented by a complete new catena of hill slope elements flanking the Harts river with a narrow alluvial plain at the base.

The topographical profile between the irrigation canals and the Harts river can be divided into three narrow parallel zones which are, from east to west, (a) Upper pediment, (b) Lower pediment and (c) Rejuvenation strip, as indicated in fig. 8.

The depth of incision of the Harts river below the upper surface of the calcrete increases from north to south; it is about 15 feet at the mouth of the Dry Harts river but reaches 120 feet at a latitude 4 miles south of Jankempdorp.

(b) Soil irrigability

Almost the whole width of the strip of land between the north canal and the HDH rivers is irrigable from Pudimoe southwards to a point 4 miles south of Hartswater; but south of that point the irrigable strip is separated from the Harts river by a parallel strip which is either non-irrigable or carries only scattered patches of irrigable land.

Because the topographic elements of the Tertiary catena are undergoing erosion as the result of the Pleistocene rejuvenation of the Harts river and its tributaries, parts of the lower pediments are loosing their cover of Kalahari sand with the result that large areas of calcrete or bedrock are exposed or carry a soil too shallow to be irrigable. Also, as much of the rejuvenation strip is undergoing erosion, these parts are too steep or stony to be irrigated. Furthermore, both the lower pediment and the irrigable parts of the rejuvenation strip have such low gradients that, in view of the absence of downward soil drainage consequent on the impermeability of the bedrock, the lateral soil drainage necessary for successful irrigation is not available. Thus the lower pediment and the rejuvenation strip carry only scattered patches of irrigable land.

Most of the upper pediment is irrigable except for some patches high up near the canals where Ventersdorp hills protrude through the cover of Dwyka and calcrete or render the soil too shallow. The irrigability of the upper pediment is not quite continuous from north to south, for it is interrupted where the Harts river is incised in the pediment at Taung and it becomes very narrow at Jankempdorp where lower pediment conditions extend far into the Dwyka-covered re-entrant in the valley side. There are also interruptions in irrigability abreast of the west canal owing to the narrowness of the upper pediment and the abundance of Ventersdorp rock hills and rises upon it.

The assessment of irrigability is complicated and in the original investigation in 1932-33 it was determined from the following factors, (a) type of soil, (b) depth of soil, (c) permeability of soil and of the hard material found under the soil in the test pits, (d) pH value of the soil and (e) abundance and type of brack (salinization) in the soil.

The factor of ground slope was not taken into account in assessing irrigability. If the absence of downward soil drainage had been appreciated at the time of the survey, perhaps surface gradient would have been considered, so that less land of inadequate surface slope would have been regarded as irrigable.

The original soil survey recognised seven degrees of irrigability and non-irrigability as follows:-

1.) Different kinds
2.} of
3.) irrigable soils.
4. Transitional - may or may not be irrigable.
5.) Non-irrigable soils and
6.} rock exposures of
7.) various kinds.

It may be that some of the troublesome localities are situated where the soils were actually mapped as transitional or even non-irrigable for soil areas of the different categories are quite intimately associated in some localities. (See the author's irrigability map of the blocks G.H.J. and K. traced from maps of the Vaal-Harts irrigability map series, but not included in this report).

4. CAUSES OF WATER-LOGGING AND SALINIZATION

Collecting together the relevant facts reviewed above, the causes of water-logging and salinisation seem to be as follows:

(a) Water-logging

The great rise in the water-table since irrigation began and the relatively poor yields of the few deep bore-holes of which records exist indicate that naturally occurring ground-water plays a very small part, if any, in the water circulation of the irrigation scheme and that water-logged conditions can be directly attributed to the excessive accumulation of irrigation water in the soil due to the following circumstances:-

1. Downward soil drainage is prevented by the almost impermeable character of the bedrock.

2. Lateral soil drainage from higher to lower ground is greatly impeded on account of (i) the very low surface gradients, usually less than 1%, and (ii) the presence of a calcrete sheet with a very uneven surface lying between the bedrock and the irrigated soil.

3. The high permeability of the Kalahari sand soil causes irrigation water to percolate beyond the range of roots before the plants have had time to make proper use of it. In consequence far more irrigation water is used than should be necessary.

4. The incoherence or friability of the Kalahari sand soil makes artificial drainage difficult on account of (i) the collapse of drainage ditch walls, (ii) the infiltration of sand into pipe drains and (iii) disruption of ditch linings by floatation on a high water-table.

(b) <u>Salinisation</u>

This is evidently the result of three circumstances additional to those that cause water-logging, viz.

1. The especially high content of soluble mineral matter in the Dwyka rocks which underlie the soil and calcrete and the leaching of this material from them by water standing in the ~~thin~~ weathered zone below the calcrete.

2. A vertical circulation of water between the mineralised sub-calcrete water and the fresh soil-surface irrigation water, a circulation which involves downward movement of the fresh irrigation water due to high soil permeability during irrigation and the return of this water to the surface by capillarity during periods when the irrigation water is cut off after it has become charged with mineral matter.

3. A climate having a high evaporation-rainfall ratio so that water returned to the surface is evaporated leaving its dissolved salt content as brack in and on the soil.

5. METHODS OF RESEARCH AND RECLAMATION

Research should be aimed first at determining whether the natural down-slope lateral soil drainage in the affected localities is or is not obstructed by irregularities in the depth and nature of the surface of the calcrete sheet or bedrock that underlies the irrigated soil.

This might be done by the use of a tracer but, as the writer has had no personal experience in their use he must discuss this matter with those who have before ~~made~~ making recommendations.

If the natural down-slope drainage is not being obstructed then the only possible remedial measure is to improve the present system of artificial drainage.

If, however, the natural down-slope drainage is being obstructed, then the nature and layout of the obstructions must, if possible, be determined. As tracer experiments will take time, it should be assumed in the meantime that obstructions exist and can be identified. Investigations with this aim that can be started immediately are:-

1. Surface geological examination of localities likely to yield evidence of the nature and form of the obstructions.
2. Re-examination of the soil type maps and data written thereon to see if it is possible to compile from them isobathic maps of the thickness of the Kalahari sand, starting at the affected localities.
3. Make experimental probings with a post-hole or other type of auger in the affected areas to see whether the form and depth of the sub-sand surface can be ascertained in this way. Then, if this is found to be possible, conduct an auger survey with a view to the identification and delineation of the obstructions.
4. Examine deep drainage ditches and their spoil banks to see if they provide any evidence as to the distribution of ridges on the calcrete surface.
5. Experiment with various resistivity techniques to see if the depth and form of the sub-sand surface can be ascertained by such means.

If all these lines of research yield negative results then again nothing can be doen except to improve the existing artificial drainage system. But, if the nature and layout of the natural obstructions can be ascertained sufficiently accurately to indicate the lateral soil drainage pattern, then it may be possible to modify the present artificial drainage system so that instead of being independent of, it augments and improves the natural drainage. If the barriers are found to consist of the calcrete walls of pens, as suggested earlier in this report, it might be practicable to expose the walls and blast breaches in them at critical points in order to facilitate the drainage of water from one pen to another.

6. COMMENTS ON RESEARCH PROJECTS ADVOCATED BY OTHER INVESTIGATORS

(a) Misconseptions regarding the geology of the area

On page 10 of A. Streutker's 1966 report, Section 3.2.(iv) certain geological expectations based on work elsewhere are stated. They include:

1. Shallow ground-water in the calcrete is connected with deep ground-water in the decomposed lava by means of dolerite intrusions.
2. Deep ground-water in a network of dykes connected with the dolerite intrusions.
3. Decomposed lava underlain by impermeable fresh lava which prevents drainage.
4. Upwelling and seeping out of ground-water.

On p. 14 of that report it is suggested that the ground-water gradient and depth should be calculated from the calculated amount of leach water and the permeability of the network of dolerite, calcrete, laterite and soil.

On p. 15 it is suggested that a geological survey should be made in order to see if the boundaries of the experimental areas chosen coincide with underground barriers or compartment barriers.

Figure 2 of that report provides a geological section.

The writer's corresponding comments are as follows:-

Page 10, (1) Ground-water in decomposed lava is not likely to come into contact anywhere with irrigation water as the almost impermeable Dwyka formations intervene. Almost all known dolerite intrusions are sheets inter-leaved with the Dwyka sedimentary rock formations so that they cannot form conduits between deep and shallow ground-water bodies.

(2) There appears to be no record of any dyke in the irrigation area except possibly one near Hartswater and another near Pokwani.

(3) The irrigated soil overlies Dwyka shale and tillite, not lava.

(4) There is no record of any spring or flowing bore-hole in the irrigation area and so there is no reason to assume any uprising or seeping out of ground-water. The water that seeps out of the ground is the irrigation water mineralized by contact with underlying decomposed Dwyka shales and tillites.

Page 14. - There is no network of dolerite, calcrete, laterite and soil and, even if there were, ground-water would not be moving in it. This is the first mention of laterite. The term laterite, as used by geologists, means lateritic ironstone and this is a ferricrete which occurs in much the same way as calcrete. The formations mentioned form an orderly, nearly horizontal, stratiform series. Except for the soil and to a lesser extent the calcrete and ferricrete they are impermeable unless weathered or cracked so that water does not move through them but through cracks in them. The network is not provided by the formations but by the cracks. It is impossible to determine the permeability of a network of cracks because their width, spacing and degree of interconnection vary from point to point in each geological formation.

Page 15. - There are probably no widely spaced, well-defined barriers such as the dykes that divide dolomite formations into compartments: there are likely to be only ill-defined, closely spaced ridges on the surface of the calcrete formation.

Fig. 2. This section probably gives an erroneous impression of the geological structure of the area.

(b) <u>Comments on certain proposals</u>

A. Streutker advocates:

1. Periodical collection of data at fixed points to follow the progress of water-level and soil salinity changes. Agreed.

2. Experiments on certain plots to determine the feasibility of pipe drainage, pump drainage and to find the optimal water-level. Agreed, but in connection with pump drainage this can only be carried out where there is a well or bore-hole in sufficiently permeable ground and where the pumped water can be removed from the area without re-entering the ground. Are both these conditions satisfied on the research plots 5K5, 6K5 and 7K5? Buried former river beds, from the materials of which pump drainage has already been undertaken, are likely to be confined to the close proximity of the Harts river as in sections H 13, 14 and 15.

3. Improving the accuracy and increasing the number of points of surface water gauging. Agreed, if feasible. It would certainly be valuable to know how much surface run-off passes across the canals from the eastern Ventersdorp rock valley side into the irrigation area to join the irrigation water by infiltrating into the soil.

4. Mapping of water-logged areas by infra-red photography. The writer has not looked into this subject and cannot comment.

5. Drilling of 40 bore-holes to depths of 200-300 feet to assist geological mapping. It would be very interesting to have say three lines of three deep bore-holes each to find the depth of the base of the Dwyka and the thickness of weathered rock underneath it, for that would indicate whether ground-water below the Dwyka is likely to play any part in the irrigation problems, but 40 bore-holes would be superfluous. Even the nine suggested are not really necessary. What would, however, greatly facilitate the collection of geological information would be for the geologist in charge to have at his disposal one 2-in. diameter core diamond drill and crew so that exploratory holes could be drilled where and when necessary in the course of the investigation.

6. Making a detailed geological map of the area. Certain localities should be carefully examined and perhaps mapped on a large scale but systematic large-scale geological mapping of the whole irrigation area would probably not be worth while. The whole area was covered

by a grid of pits when the original soil type maps were compiled and far more geological information is likely to be gained by studying those maps than by doing further field mapping.

7. WILD CAT SUGGESTIONS OUTSIDE THE GEOLOGIST'S PROVINCE

It is appreciated that the following suggestions may be quite impracticable for technical, legal, economic or other reasons but they are given for what they may possibly be worth.

1. Cut down the irrigation water in affected localities by some arbitrarily determined fraction until sufficient water balance data have been accumulated to ascertain the optimal quantity of water required.

2. Replace furrow irrigation by spray irrigation in the affected areas in order to make a more economical use of the irrigation water.

3. Replace ditch drains by pipe drains in the affected localities and lay the pipes in gravel beds placed at the bottom of the ditches to screen out the sand. Suitable gravel might be made available by excavating, crushing and screening incoherent parts of the calcrete sheet.

4. Introduce suspended clay into the irrigation water in the affected localities with a view to reducing the permeability and incoherence of the soil.

8. THE POSITION REGARDING SECULAR RAINFALL VARIATION

The Vaalharts Irrigation Settlement lies in Weather Bureau Rainfall District No. 19 which is referred to by the writer as the Vryburg rainfall district.

Figure 9 provides the residual-mass annual rainfall curve for the Vryburg rainfall district compiled from the published data in "District Rainfall" (1960). The most accurate long-term mean annual rainfall is regarded as furnished by the 36-year period 1916 to 1952 and comes to 485.5 mm.

It will be noted that the whole period of record is divisible into two sub periods with different annual means, viz.

(a) 28-year period (1908-36) with an annual mean 3.4% below the long-term annual mean and

(b) 28-year period (1936-64) with an annual mean 3.4% above the long-term annual mean.

The form of the curve suggests that during the next 28-year period the mean annual rainfall will again be below the long-term mean but, at the same time, the shorter fluctuations suggest that the mean annual rainfall during the next four years will be about 525 mm, i.e. about 10% above the long-term mean.

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Geologist.

Geological Survey,
Pretoria.
17/9/1967.

ADDENDA AND CORRIGENDA

To sources of information should be added:

1. Geological Survey Sheet 2724B - Pudimoe and 2725A - Schweizer Reneke.

2. Explanation of above sheet by Van Eeden O.R., De Wet, N.P. and Strauss, C.A. 1963.

3. Boorplekaanwysing vir Water in Suidwes-Transvaal. Bull. 34 by De Villiers, S.B. 1961.

4. Course of lecture notes on Hydrogeology in South Africa (unpublished) by Vegter J.R., Wilson P.T. and Temperley B.N.

5. King, L.C. (1957). The uniformitarian nature of hillslopes. Trans. Geol. Soc. Edinburgh. Vol. 17. pp. 81-104.

6. Miln G. (1936). Normal erosion as a factor in soil profile development. Nature, 138 (3491), p. 548-549.

The authors of Explanation of Sheet 2724B - Pudimoe and 2725A - Schweizer Reneke (1963), which covers the Dry Harts valley northward from Taung almost to Vryburg, make numerous relevant observations. Items (4) and (5) below are from De Villiers (1961) to whom the reader is referred by the authors mentioned. These observations are as follows:

1. Owing to intense weathering and softness, Dwyka tillite and shale are rarely exposed.

2. Much of the Dwyka formation is represented by erratic boulders and boulder clay.

3. The Dwyka tillite is a very poor aquifer as water is found only in occasional joints and fractures. The chance of striking water in Ventersdorp lava overlain by tillite is also poor because the lava is seldom weathered.

4. The Dwyka shale has a low permeability and does not yield sufficient water to bore-holes.

5. Surface-limestone occurs in various ways which include:
   (a) On the Ghaap plateau "aars" occur over dykes in the dolomite. They are long ridges of limestone 30 ft. wide and 15 feet high covered with dense bush.

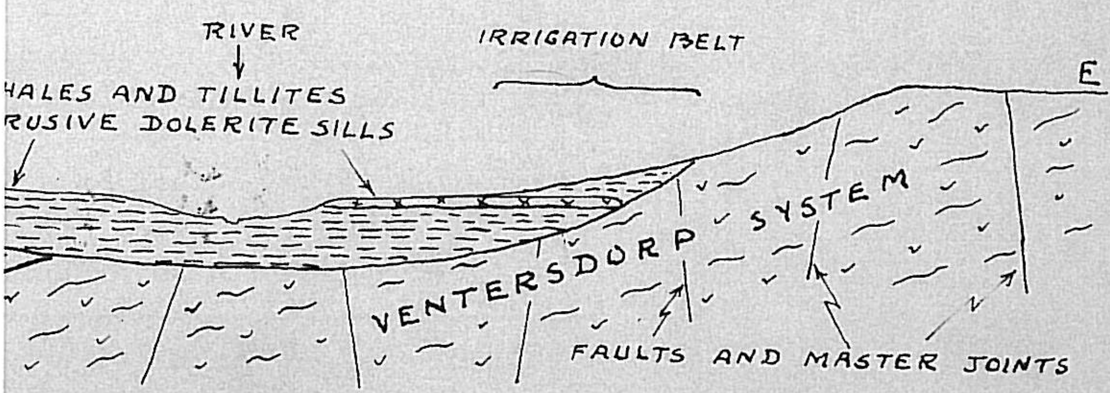
(b) Calcrete terraces are often well-developed on the Dwyka but also occur on the Dolomite. They are lines of calcrete tufa narrow, long and fairly straight. Enclosed in the calcrete are blocks of bedrock and boulders of Dwyka origin.

It is evident from the above notes that the Dwyka formations are much more strongly and deeply weathered than the present author's report suggests and that the shales have reverted at the outcrop to clays and the tillites to boulders in boulder clay. The tillites are generally covered at the outcrop by residual deposits of their own boulders.

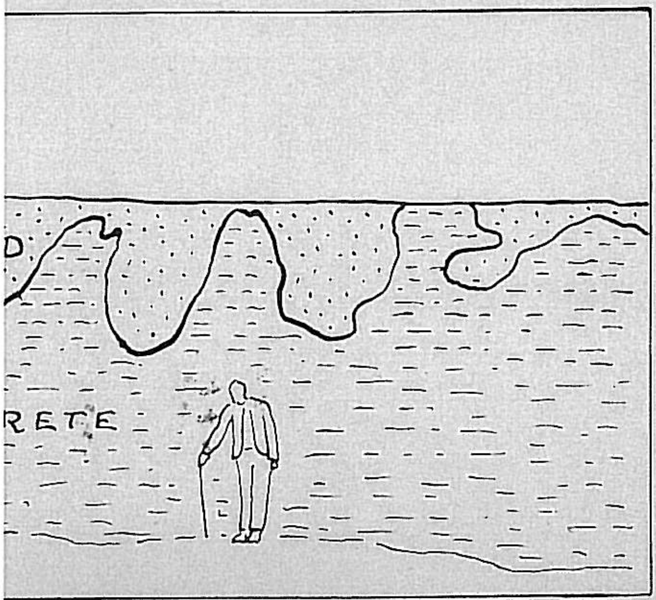
This does not alter the picture presented regarding ground-water for the clays derived by the weathering of the Dwyka are even more impermeable than the fresh parts of these formations.

The "aars" and calcrete terraces mentioned presumably developed within or below a former covering of Kalahari Sand which has been subsequently removed mainly by wind action. The calcrete ridges referred to in the writer's report may well be examples of the calcrete terraces of the Pudimoe Sheet. As they are said to be well developed on the Dwyka, it is not improbable that they occur under the sand in the irrigation belt as the writer has suggested.

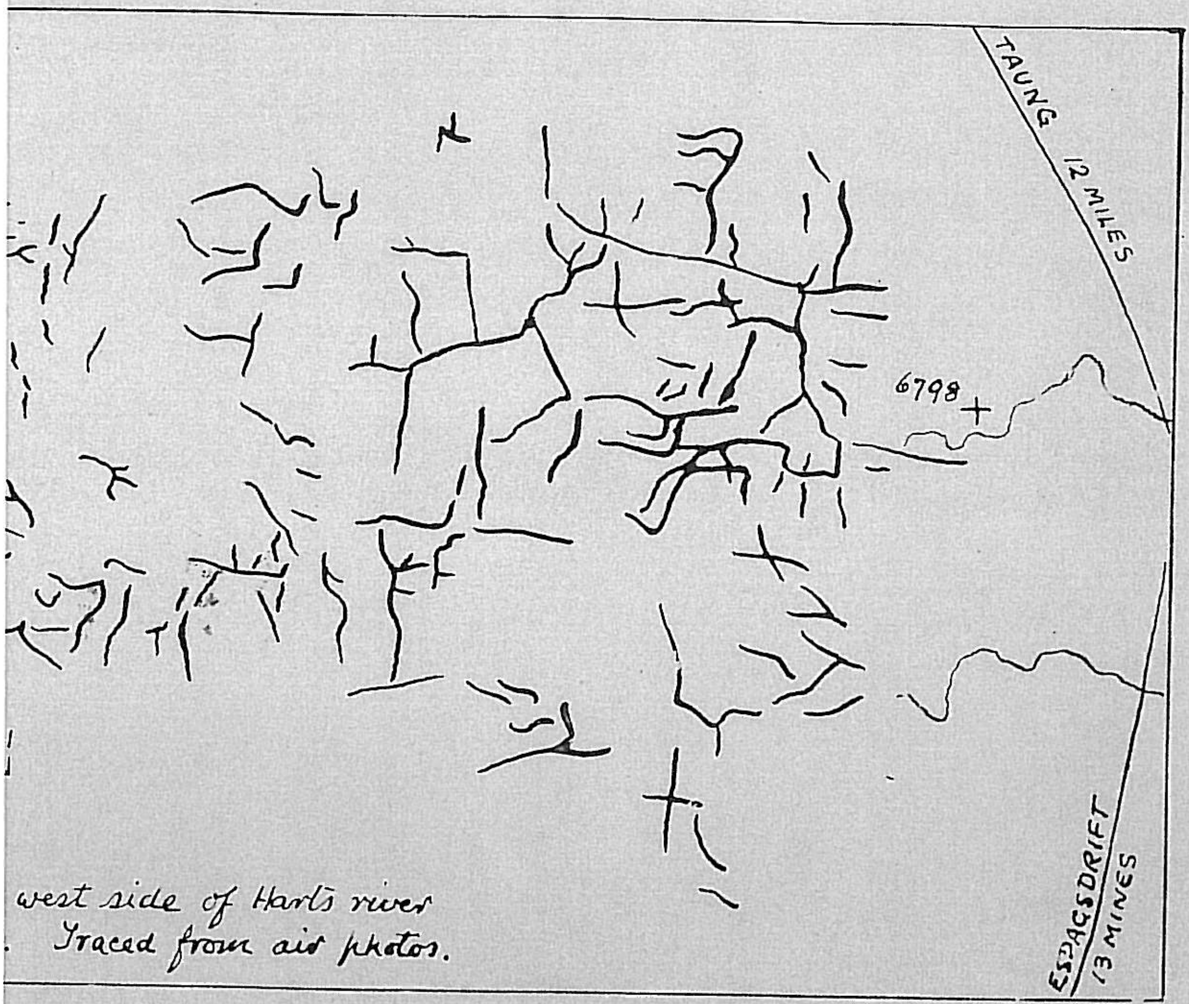
B. N. Temperley.
23.8.67.



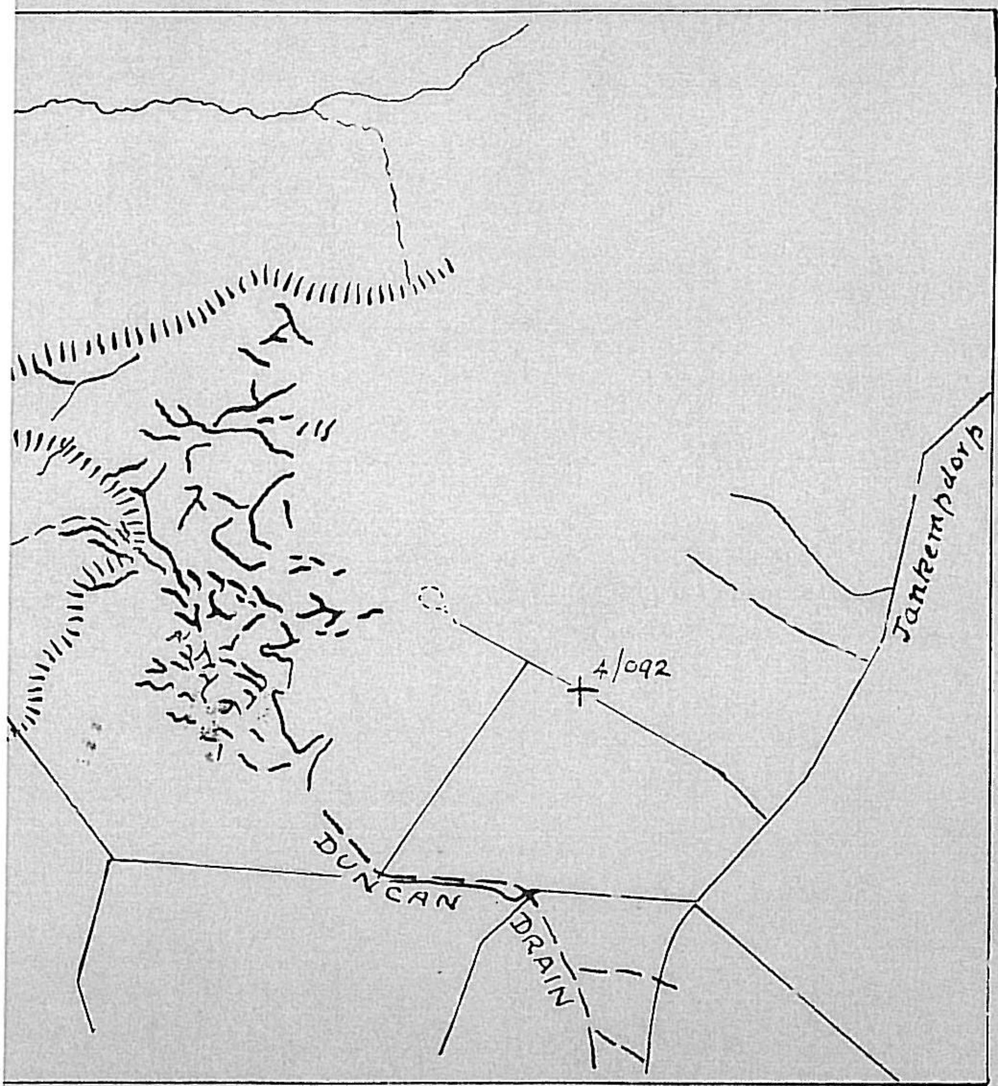
oss the Harts – Dry Harts valley. Kalahari Sand
grammatic.



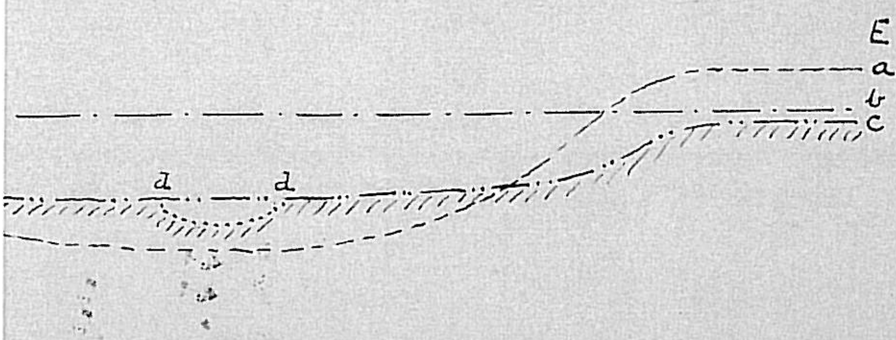
Sectional exposure of "Kalahari
on Lime" south of Modder River Station
photo by C.R. v.d. Merwe (1940), plate 11,



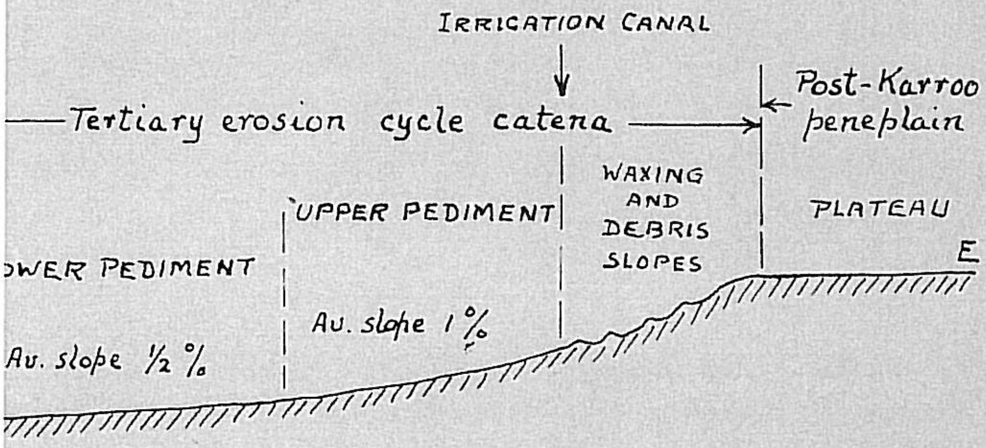
west side of Hart's river
. Traced from air photos.



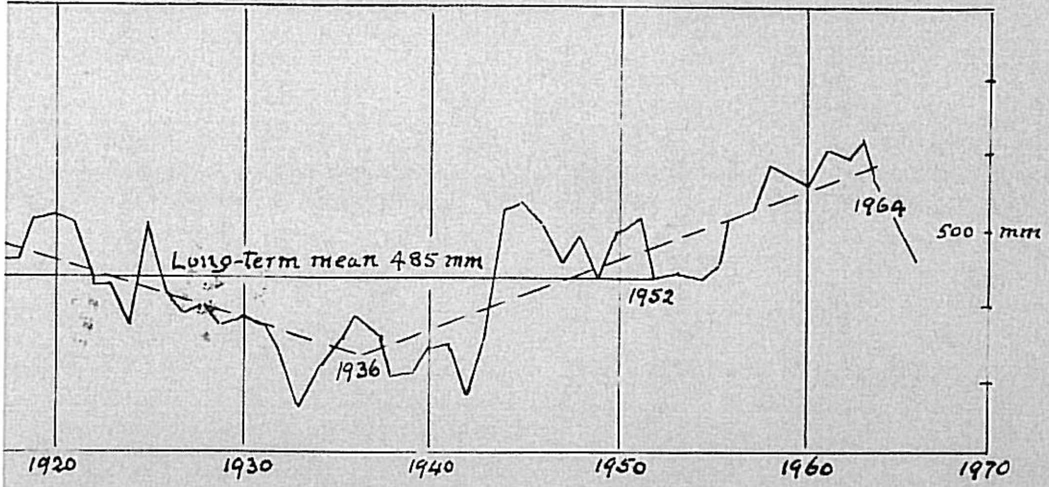
ear Duncan Drain, West Canal, 12 miles southwest of
Traced from air photos.



section across the Harts valley showing the
surfaces of four different ages. Diagrammatic.
b-b post-Karroo, c—c (?) end-Tertiary and



aphical section across the eastern side of the Harts
elements of the topographical catenas of three
Diagrammatic. The upper pediment of the
a is largely irrigable but its lower pediment
tocene erosion surfaces carry only scattered
rigable land.



mass (cumulative departure from the mean) annual
rve for Weather Bureau Rainfall District 19 (Vryburg).
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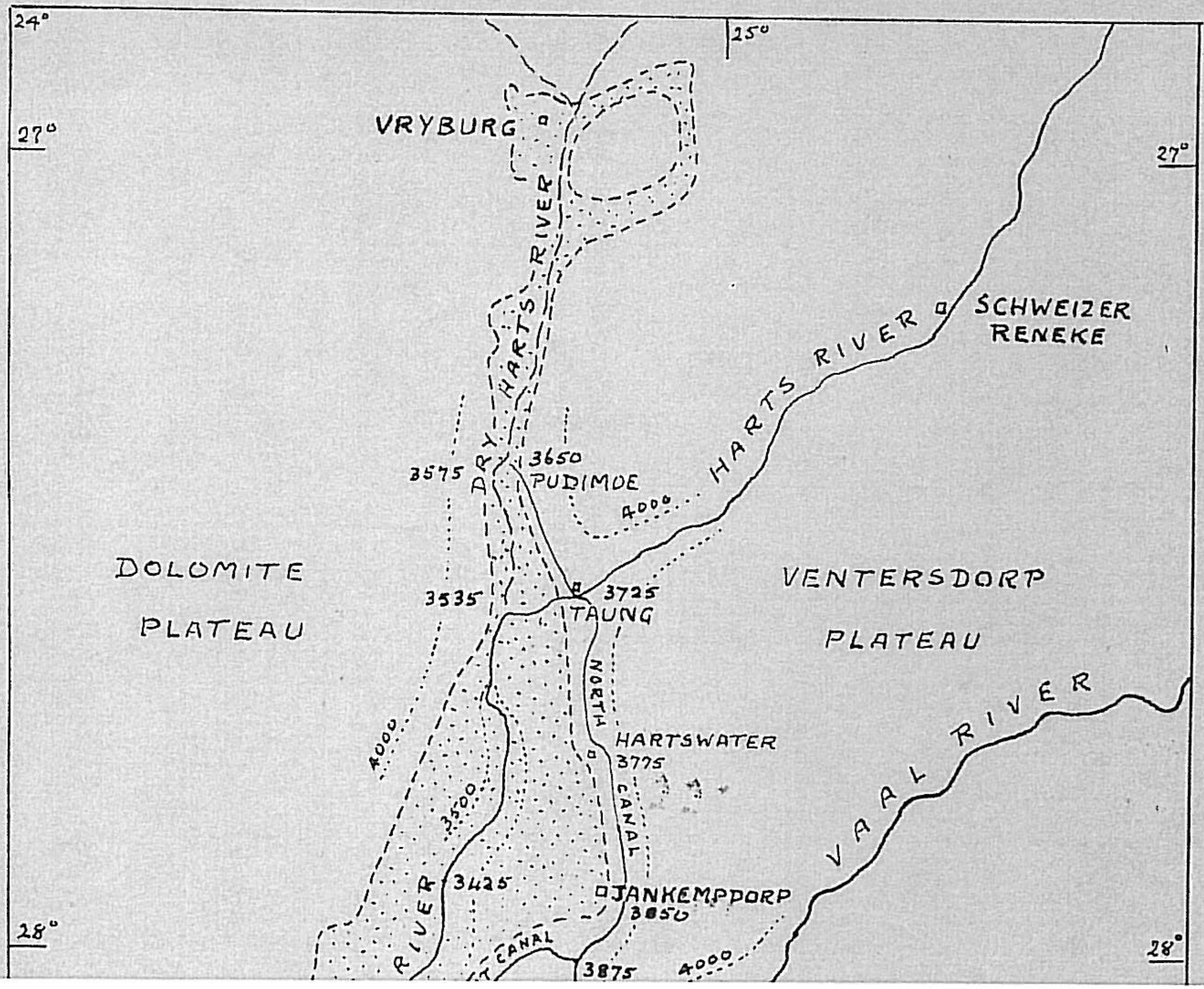

24°
25°
27°
27°
28°
28°
VRYBURG
DRY HARTS RIVER
HARTS RIVER
SCHWEIZER RENEKE
3575
3650
PUDIMOE
4000
DOLOMITE PLATEAU
VENTERSDORP PLATEAU
3535
3725
TAUNG
NORTH CANAL
HARTSWATER
3775
4000
3500
VAAL RIVER
RIVER
3425
JANKEMPDORP
3850
CANAL
3875
4000